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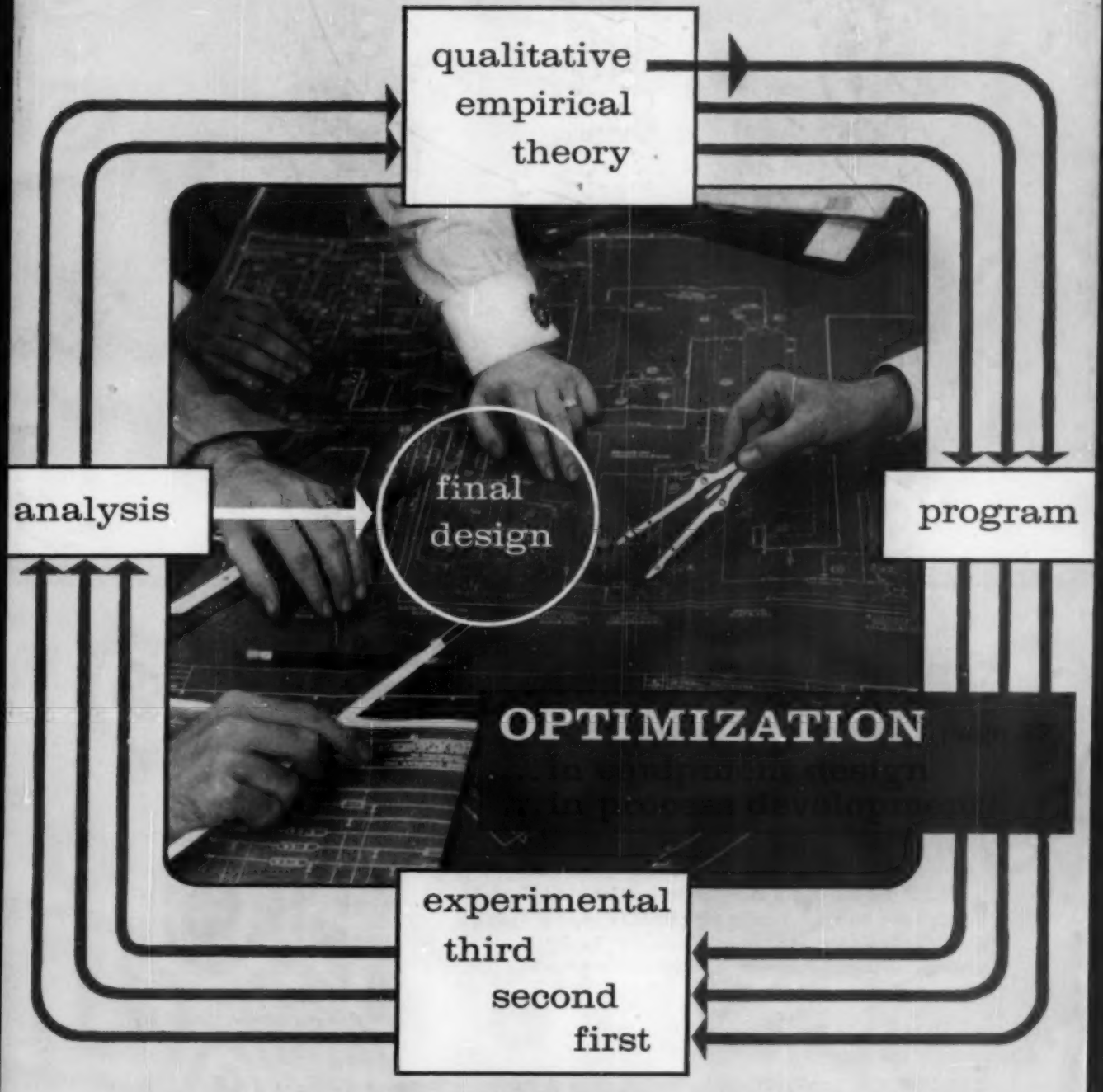
CHEMICAL ENGINEERING PROGRESS

AUGUST 1960



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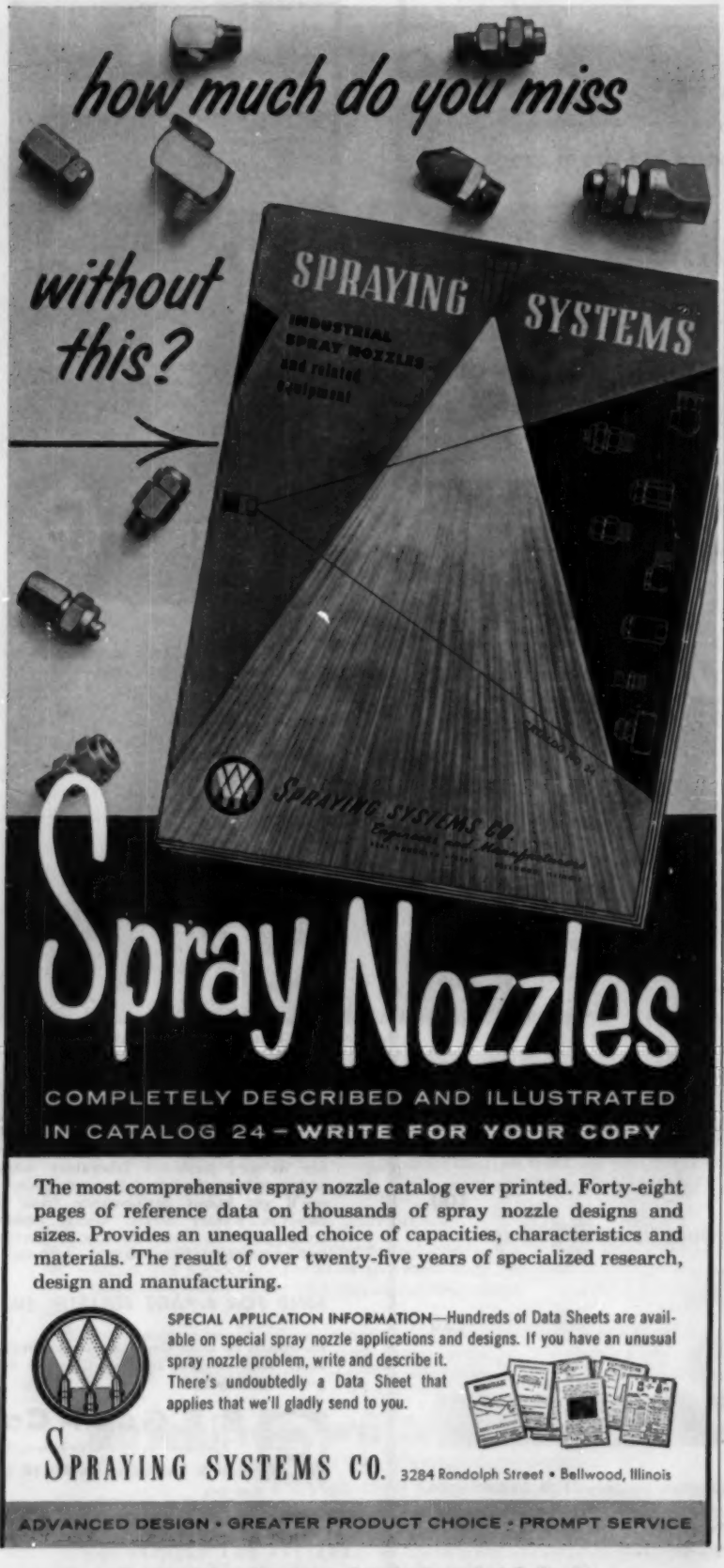
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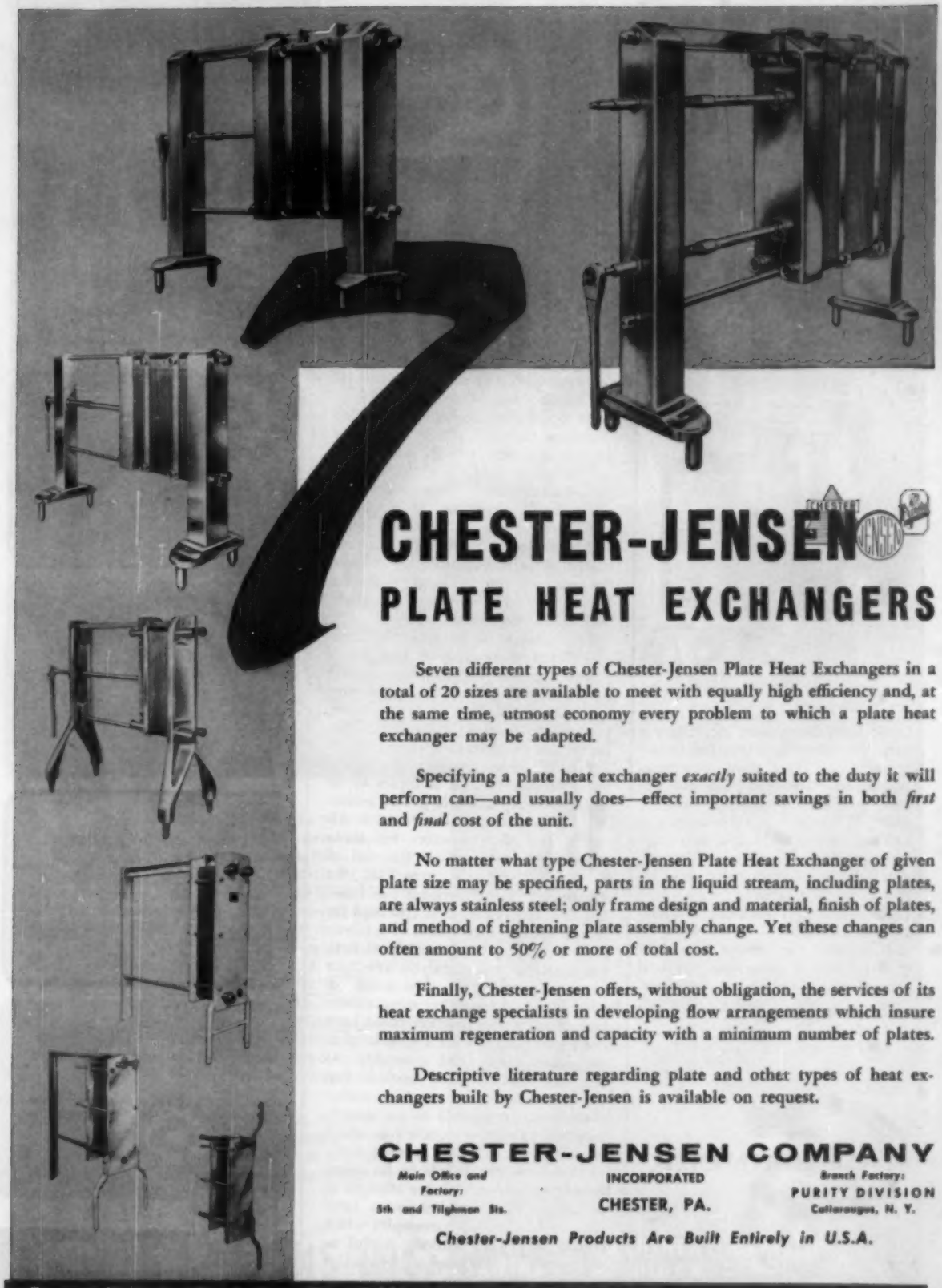
book reviews

REACTION KINETICS FOR CHEMICAL ENGINEERS, Stanley M. Walas, McGraw-Hill Book Co., New York, N. Y. (1959), 338 pp., $9.50.

The text by Stanley M. Walas entitled *Reaction Kinetics for Chemical Engineers* is another in the McGraw-Hill Chemical Engineering Series which includes the earlier work on this subject by J. M. Smith. This present effort, according to its author, has been written with the "needs of the undergraduate chemical engineer . . . foremost in mind". Thus it competes with the text by Smith both in subject matter and in the matter of its intended audience. The subjects covered represent the usual listing of topics of importance to the field including the fundamentals of both non-catalytic and catalytic, homogeneous and heterogeneous reactions, simultaneous reaction and heat transfer, an analysis of some reactor types, a discussion of scale-up methods, and a discussion of various industrial reactors. In addition, a brief chapter entitled "Mathematics for Review" is presented, covering ordinary differential equations, Bessels equations, numerical and graphical calculations, numerical solution of differential equations, and partial differential equations. An extensive bibliography on the subject is presented in the first of two appendices, the second being devoted to constants and conversion factors. All of this is accomplished in some 338 pages.

This outline may seem to the reader to include a rather considerable amount of material in one relatively thin volume—it most certainly seems so to this reviewer. The field of reaction kinetics and reactor dynamics has progressed quite far in the past few years. It is not obviously a field which should be covered at the undergraduate level the division of opinion on this point being amply illustrated by the fact that it is not universally included as part of the undergraduate chemical engineering program. When such a course is presented at the undergraduate level, it cannot encompass the entire field unless it amounts to little more than a survey of "selected topics". Hence, if the author really intended the text to be for undergraduate consumption, he might have been better advised to limit his coverage to fewer topics and to treat these more thoroughly. There

continued on page 8



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Books

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is need for a *good* text for a senior course in this area. Such a text would best present the limited number of unifying ideas which pervade the field in order to give the students some grasp of the scope of the subject and the inter-relationships existing among the various parts without trying to present the subtle details. This text fails in this regard.

For example, collision theory is covered in two pages; two additional pages are devoted to "Energy Distribution" and lead to the presentation of the partition function; two pages are devoted to the notion of the activated complex; two pages are devoted to "Energy and Mechanism". All of those topics occur in Chapter 1, titled "Fundamentals," to which the author devotes approximately 27 pages. Numerous other examples of this type of presentation, which this reviewer considers as "spotty", are easily found throughout the text. In general, most of the subjects in the book are presented in such a manner as to leave the reader (the student) with the feeling that they are each complete and totally unrelated.

For these same reasons, the book would not make a good text for a graduate course. No subject is treated with sufficient depth or insight into the interrelationships existing among the various parts to make it suitable for an advanced level of study.

Finally, this reviewer finds the order of presentation of topics to be less than fully satisfying. The author discussed homogeneous reaction kinetics and then reactors for these types of reactions. Near the end of the text (chapter 9, page 228), he introduced "Heterogeneous Catalysis" but then did not include (perhaps for lack of space) a treatment of catalytic reactors. If the fundamentals of both non-catalytic and catalytic reactions were presented first, then much of what was said regarding simultaneous heat transfer and reaction could have been generalized with a gain in clarity, cohesiveness, and generality. As it is, the student must conclude that catalytic reactors are another matter entirely—to be treated as an entirely separate subject—a conclusion which is certainly not to be promulgated.

There are two points to be raised about the book which are strongly in its favor. First, it contains a large number of illustrative examples which should be either directly useful or suggestive to the teacher. Second, it

continued on page 10

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Books

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includes an excellent bibliography of kinetics and reactor dynamics literature.

Reviewed by H. E. Hoelscher, chairman of Department of Chemical Engineering, The Johns Hopkins University, Baltimore, Md. This review was written in Madras, India, where Hoelscher is on UNESCO assignment to the Alagappa Chettiar College of Technology, University of Madras.

PROPERTIES OF MATTER, F. C. Champion and N. Davy, Philosophical Library, New York, N. Y. (1959), 334 p., $10.00.

This is the third edition of a book originally published in the 1930's. The authors are physicists and naturally have written a book of interest primarily to physicists. The *Properties of Matter* is not, however, a text book to be used in a beginning physics course since the mathematics includes ordinary and partial differential equations. The book is somewhat specialized, this being the authors' intention.

A number of topics which will be helpful to chemical engineers who are primarily interested in the experimental determination of fundamental properties such as surface tension, viscosity, the compressibilities of solids and liquids, and diffusion coefficients in the liquid phase, are discussed in the book. Many of the classical techniques used to measure these properties are discussed from both the theoretical and practical viewpoints. In this connection, the authors would have helped the experimentalist a great deal if they had included more of the recent references in order that the details of the various experimental techniques could be obtained quickly.

There are, to be sure, a number of chapters which will be of only academic interest even to the majority of the experimentally oriented chemical engineers. This would include the material on acceleration due to gravity, Newtonian constant of gravitation, elasticity, seismic waves, and methods of determining Planck's constant. Also, they will find the discussion on errors of measurement insufficient.

To the majority of chemical engineers *Properties of Matter* contains little material of interest. For example, many chemical engineers need experimental data on the fundamental properties or correlations (empirical, or otherwise) which will permit them to predict values for these properties. The book contains neither the data (not even for pure substances) nor the correlations. Also, a number of areas—such as the determination of phase equilibria and thermal data—of vital interest to chemical engineers are not included in the book.

Basically, the authors are not concerned with the uses to which data on the physical properties may be put, but only the experimental determination of the properties and the theory which underlies some of the experimental techniques.

Reviewed by James H. Weber, chairman of the Chemical Engineering Dept., University of Nebraska, Lincoln, Nebraska.

INVENTIONS, PATENTS, AND THEIR MANAGEMENT, A. K. Berle and L. S. DeCamp, D. Van Nostrand Company, Inc., New York, N. Y., (1959), 602 pp., $12.50.

Correction

In the June CEP the review of "Chemical Engineering Calculations" by Ernest J. Henley and Herman Bieber was written by G. C. Keeffe of Newark College of Engineering, whose name was inadvertently omitted.

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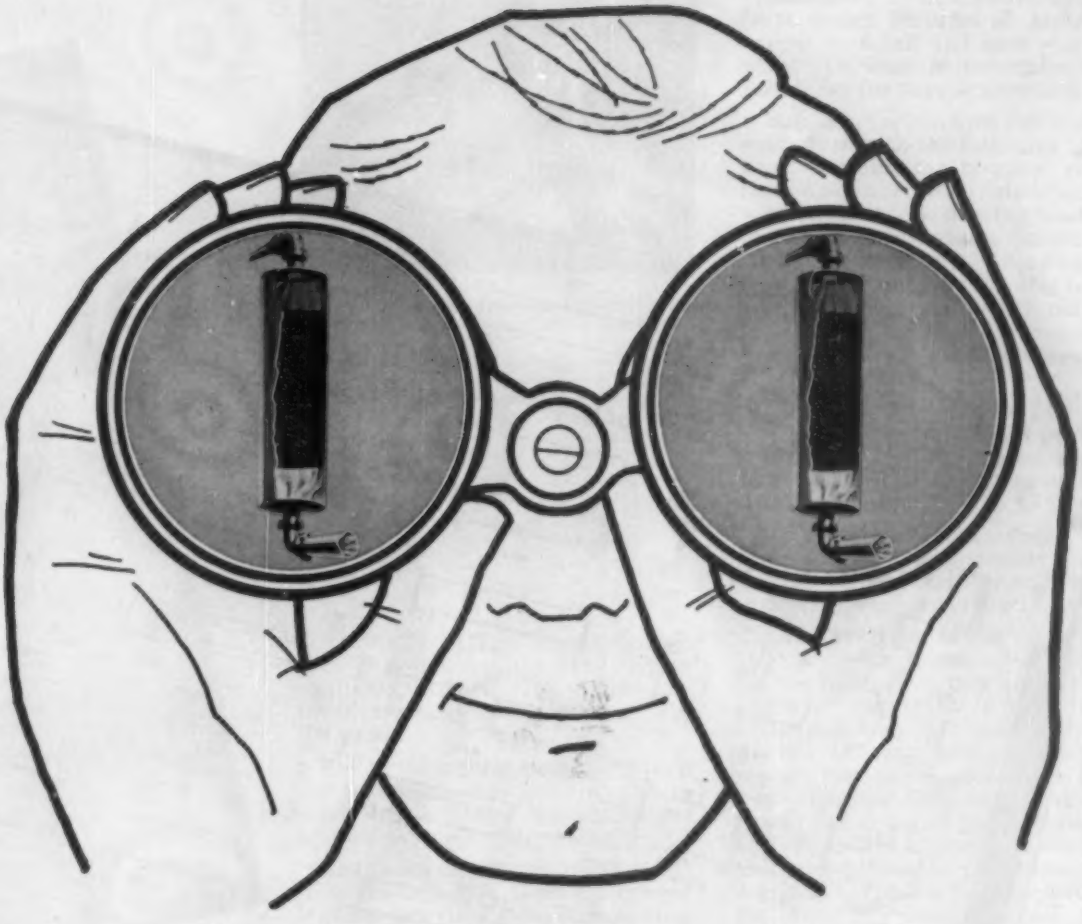

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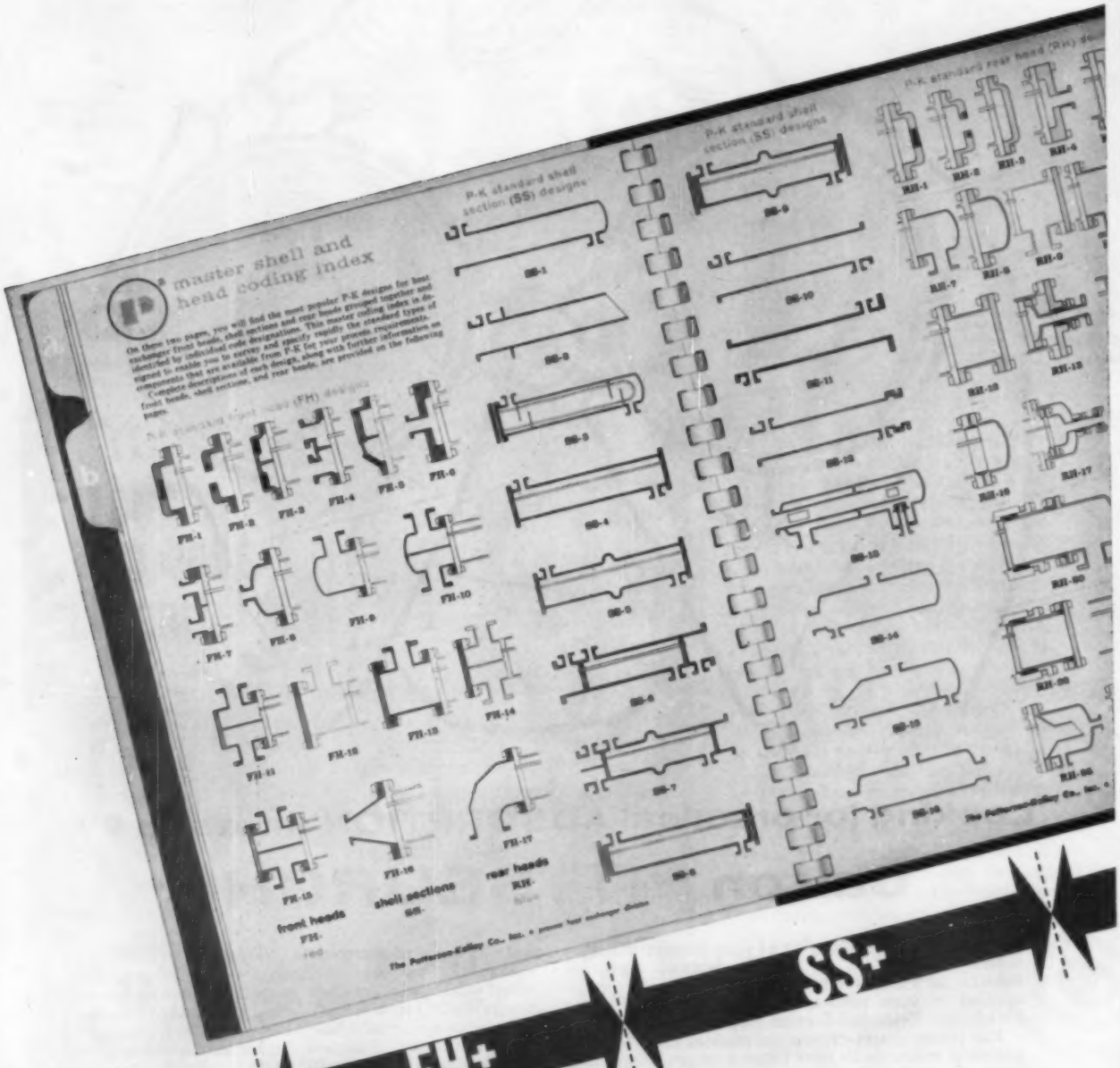
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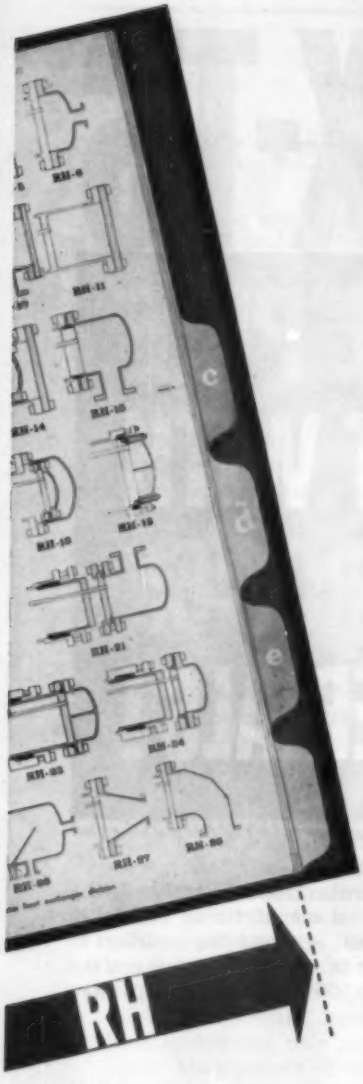

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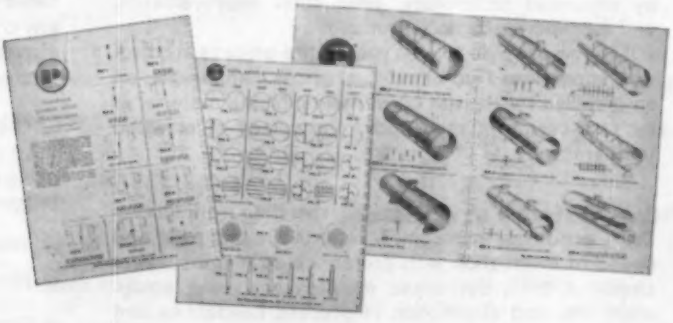

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Complete corrosion protection: Fluoroflex-T, the proprietary Teflon® product manufactured and fabricated solely by Resistoflex, is completely resistant to any chemical (except high-temperature fluorine and the molten alkali metals) up to 500° F.! It combines optimum strength and non-porosity.

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Stock value reliable index of performance

Increasing sales volume does not necessarily reflect wise management decision, nor reflect company performance, if return on investment is not safeguarded.

IF IN 1935 YOU HAD PUT $1,000 into Hooker Chemical stock, you would now have approximately $62,000 in the kitty.

Figures recently published by Stanford Research Institute trace the history of a $1,000 investment in each of 65 leading chemical and petroleum companies. (See partial listing in accompanying table.) Base year chosen was 1935, except for companies whose stock was not then publically available. Data for each company include the value of the stock, cash dividends paid, stock splits or dividends, and cumulative value of stock plus dividends.

The table lists also the value of the stock for each company at the end of 1955, 1957, and 1959, resulting from the original $1,000 investment, plus the percent over-all change for each company for the period 1955-1959. Use of this four-year period, says the Stanford Research report, avoids the distorted indication of stock appreciation values which would have resulted from considering only the last two years. Stock values at the end of 1957 for most of the companies were considerably lower than for the preceding period and, "it is desirable not to confuse recovery with actual growth in value." At the beginning of this year (1960), however, all but three of the companies in the series studied registered higher stock values than for two years ago. In fact, more than half of the stocks which declined had recovered and exceeded their former value.

Stock value seen reliable index

Use of common stock performance as a criterion of corporate success, according to the Stanford researchers, avoids a major pitfall inherent in use of the most popular index of company performance—growth in sales volume. Increasing sales volume, they point out, does not necessarily reflect wise management decision, if return on investment is not maintained. For instance, if a large chemical company were to absorb as operating divisions ten other large chemical companies, the apparent increase in sales volume of the parent company would be "epoch-making." However, the new combination might be so unwieldly that return on investment could deteriorate; this would eventually be reflected in a lower market value for the parent company stock.

	Year of Original $1,000 Investment (1935 Unless Otherwise Noted)	Value of Stock (Dollars)			% Change In Stock Value
		Dec. 31 1955	Dec. 31 1957	Dec. 31 1959	Since 1955 by 12/31/59
Air Reduction		716	894	1,495	108.8
Allied Chemical		3,084	1,990	3,169	2.8
American Agricultural Chemical		4,249	3,725	5,085	19.7
American Cyanamid		4,576	5,949	7,966	74.1
American Potash & Chemical		4,665	4,518	4,985	6.9
Atlas Powder		2,719	2,369	3,677	35.2
Celanese Corp. of America		2,112	1,150	3,391	60.6
Chemetron	(1937)	2,286	3,403	2,930	28.2
Commercial Solvents		967	463	749	–22.5
Diamond Alkali		2,642	1,941	3,715	40.6
Dow Chemical		8,851	8,048	15,326	73.2
Du Pont		6,630	5,061	7,577	14.3
Food Machinery and Chemical		3,838	3,037	6,170	60.8
Glidden		1,667	1,259	1,891	13.4
W. R. Grace	(1951)	1,579	1,361	1,522	–3.6
Harshaw Chemical		6,066	3,635	4,951	–18.4
Hercules Powder		6,225	5,717	10,326	65.9
Heyden Newport Chemical		3,700	2,300	3,850	4.1
Hooker Chemical		62,305	37,691	61,921	–0.6
Interchemical		2,992	2,269	6,653	122.4
International Minerals & Chemical		3,779	3,247	3,748	–0.8
Koppers	(1944)	1,739	986	1,324	–23.9
Merck		13,426	20,534	39,123	191.4
Michigan Chemical	(1946)	363	749	998	174.9
Monsanto Chemical		4,846	3,756	6,072	25.3
National Distillers & Chemical		2,121	2,091	3,435	62.0
Nopco Chemical		2,183	2,006	5,137	135.3
Olin Mathieson Chemical		3,892	2,702	3,727	–4.2
Parke, Davis		921	1,355	3,083	234.7
Pennsalt Chemicals		2,080	2,166	3,927	88.8
Chas. Pfizer	(1942)	13,624	17,166	30,829	126.3
Pittsburgh Coke & Chemical	(1937)	6,191	4,002	6,282	1.5
Procter & Gamble		3,150	3,567	5,670	80.0
Rohm & Haas	(1949)	7,749	6,316	15,257	96.9
Spencer Chemical	(1949)	3,070	2,210	3,503	14.1
Stauffer Chemical	(1953)	1,836	2,331	4,563	148.5
Sun Chemical		1,488	891	1,342	–9.8
Union Carbide		4,625	3,900	6,174	33.5
United Carbon		2,230	1,929	3,199	43.5
Vick Chemical		2,662	2,905	10,892	309.2
Virginia-Carolina Chemical		7,999	2,684	5,473	–31.6

continued

To export or not to export

Canadian government policy seen encouraging export of raw materials at expense of domestic manufacturing. Corollary—fewer jobs for chemical engineers in Canada.

IN THE CANADIAN MINING INDUSTRY, there are about twice as many chemical engineers as there are geological engineers. This, and some other surprising facts, came out of a recent survey, results of which have been made public by W. N. Hall, president of the Chemical Institute of Canada.

The survey covered the employment of both chemical engineers and chemists over the whole range of Canadian industry, as well as in government service and teaching. (A breakdown of the figures is given in the accompanying table.) It will be noted that the figures include a total of about 6,000 chemical engineers and chemists; this is believed to represent a sample of about 60% of all those in Canada.

Heaviest concentration of chemical engineers and chemists is in chemical products manufacturing; these however, make up only slightly over 28% of the total. Government service accounts for about 9%, but the most impressive percentage (43%) is that represented by industries other than manufacture of chemicals. These industries include foods and beverages, rubber and leather products, textiles, wood and paper products, iron and steel, nonferrous metals, electrical apparatus, non-metallic minerals, petroleum and coal.

Significant indication—while the chemical industry itself seems to employ considerably more chemists than chemical engineers, a large proportion of other manufacturing industry employs more chemical engineers than chemists.

Primary and secondary industries

Canadian exporting industries are far less important employers of chemical engineers and chemists than is the domestic economy; in fact, probably only about 19% of Canadian chemical professionals owe their employment to the primary resource, or export industries.

Hall, in his analysis of the survey results, views with misgiving the continuing Canadian government policy which supports the export industries at the expense of native manufacturing enterprises. He points out that Canadian manufacturing climbed only from 29 to 32% of total national output from 1946 to 1956, and today, because of rapid developments in other sectors, "there is some evidence that it may have declined below the 32% mark."

"Clearly," continues Hall, "our interests as professional chemists lie in the continued expansion of Canadian secondary industry, rather than the resource industries which ship raw Canadian goods out of the country before we chemists can get our hands on them. We believe that government policy should be directed to developing new secondary industries which will demand, use, and upgrade that pulp and paper, metal and ore which is presently so 'surplus' that we must sell it abroad."

	Chemists		Chemical Engineers		Total	
Type of Employer	Number	% of Total	Number	% of Total	Number	%
Mining	94	3	380	14	474	8
Manufacturing						
Foods and beverages	285	10	89	3	374	6
Tobacco	8	..	3	..	11	..
Rubber and leather	114	4	110	4	224	4
Textiles	79	2	92	3	171	3
Clothing	..	..	..	..	..	..
Wood and paper products	227	8	332	12	559	10
Iron and steel products	59	2	90	3	149	3
Transportation equipment	19	1	39	1	58	1
Non-ferrous metal products	89	3	213	8	302	5
Electrical apparatus	82	3	41	1	123	2
Non-metallic mineral products	81	3	57	2	138	2
Petroleum and coal products	117	4	272	10	389	7
Chemical products	943	31	708	25	1,651	28
Miscellaneous products	2	..	4	..	6	..
Construction	2	..	17	1	19	..
Transportation, storage and communication	31	1	12	1	43	1
Public utility	8	..	62	2	70	1
Trade, wholesale	3	..	..	..	3	..
Retail Trade	..	..	1	..	1	..
Finance	..		..		..	
Education (only University)	224	7	104	4	328	6
Dominion Government	346	11	64	2	410	7
Municipal Government	7	..	10	..	17	..
Provincial Government	118	4	11	..	129	2
Business Service (Incl. Consultants)	93	3	97	4	190	4
Total	3,031	100	2,808	100	5,839	100

Chemical industry rates high for next decade

Investment survey shows some sections of industry likely to increase production twice as fast as rest of economy.

SPECIAL METALS, AGRICULTURAL chemicals, rocket fuels, nuclear-based chemicals and plastics are particularly likely bets to increase production at over twice the rate of our entire economy within the next ten years. While not all chemical products are of this superior growth potential, the chemical industry as a whole does fall into this category, a study reveals. Results of the survey of the probable source of growth industries for the upcoming 1960-70 decade, made by the Wall Street Firm, Dominick & Dominick, are published in *A Ten Year Investment Forecast*. Superior growth potential is defined as the ability to increase sales by at least 80 percent in this ten year period, and also to maintain a proportionate growth of earnings. The chemical industry rates high in this overall picture.

Plastics costs coming down

Some new plastics will be introduced within the next decade, the forecast points out, but less frequently than in the past. The primary emphasis of the laboratories will be to reduce costs for present plastics and to provide them with special characteristics for special applications. An increasing share of the textile and packaging markets will come to the chemical industry from plastics for fibers and films. As these fields enlarge, and prices for plastics are brought down, they will compete more directly with low cost volume materials such as cotton and paper.

Glass containers also face replacement by the less fragile and lighter plastics. Structural use of plastics are increasing, as surface coatings for plywood and steel, and as laminates with glass fibers where strength is required. Plastics will be preferred, it is anticipated, not as cheap substitutes for natural products, but as the better and cheaper materials they have proved themselves to be in so many cases. Lower manufacturing and maintenance costs and longer life are also positive factors.

Drugs and research going up

The forecast for related industries is equally optimistic. In drugs, a marked increase is predicted for foreign sales, which even now average about 30 percent of the total. For domestic, an estimated 85 percent rise is in the cards. Current government investigations should have no retarding effect, for some practices unquestionably need correction. The industry faces a continuing challenge in the necessity to solve major health problems.

In research, where the rate has been accelerating since 1950, a $15 billion expenditure seems probable within a year or two; $35 billion by 1970. Computers are of special importance, for the development of the electronic computer could be the outstanding industrial achievement of our time. For example, the most profitable product mix for oil refineries can be adjusted automatically to every change in the market for raw materials and products. And, of course, the extensions in the use of automation that are made possible by the computer are also noteworthy.

Soviet use of engineers studied by U. S. mission

A six man EJC delegation has returned after spending a month in the USSR studying utilization and allocation of Soviet engineers and technicians. A Soviet team will visit the U.S. at a later date. Pictured above is the U.S. team. Seated (left to right) are: W. E. Lobo, consulting chemical engineer, New York; H. R. Beatty, Wentworth Institute, Boston, Mass. Standing (left to right are: C. S. Dargusch, Engineering Manpower Commission, EJC; O. Hoeffding, Rand Corp., Santa Monica, Calif.; S. B. Ingram, Bell Telephone Laboratories, Murray Hill, N. J.; R. M. Mahoney, Union Carbide Corp., New York.

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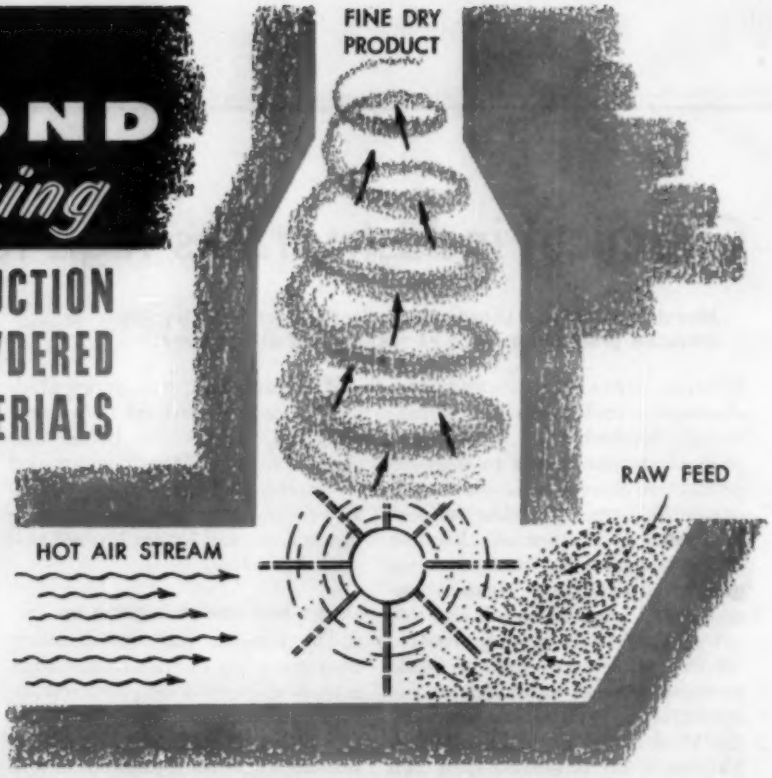

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In the manufacture of powdered materials, Raymond Flash Drying stands out as a unique, modern system for simplifying processes, developing new products and handling special problems.

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U.S.I. CHEMICAL NEWS

August ★ A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries ★ 1960

Polyethylene Used for Insulators in Nuclear Weapons Research Work

Two large polyethylene insulators, 18½ inches in diameter, have been made for use with a unique electrical switch in the discharge of heavy current loads from large condenser banks. Insulators and switch are reported to be part of research equipment used by nuclear physicists in the simulation and study of various aspects of nuclear weapons systems.

Polyethylene was chosen for its good insulating qualities, it is reported. Each insulator is said to be capable of withstanding voltages in the neighborhood of 100 kilovolts. The insulators were carefully milled to insure design compatibility with the special two-million-ampere switch.

Milling polyethylene insulator for use with unique electrical switch in nuclear weapons research. (Photo courtesy Boeing Airplane Co.)

New Chlorine Booklet Is Offered by U.S.I.

Facts about chlorine are detailed in a concise new booklet just released by U.S.I. Illustrated with photographs, drawings, graphs and charts, the 28-page booklet describes chlorine's chemical and physical properties in detail, and gives information on shipping, handling, safety measures and applications.

The company is preparing a similar publication on caustic soda which will be available shortly. For your copy of the chlorine booklet, write to the Technical Literature Dept., U.S.I. Chemical News, 99 Park Avenue, New York 16, N. Y.

Sodium Process Developed by U.S.I. Proves Economical for Desulfurizing Coke Oven BTX

Thiophene Levels in Benzene-Toluene-Xylene from Coke Oven Sources Reduced to Less Than 1 PPM. Purities Match Those Of Petroleum Products, with Treating Costs of Only 1-2¢/Gal.

Recent demands for low-thiophene benzene and toluene are creating new interest in desulfurization processes. To remain competitive with low-thiophene petroleum fractions, coke oven producers today must further treat their light oils to reduce thiophene content. Usual specifications are less than 1 ppm. Workable treating processes developed so far have proved economical only for very large scale coke oven operators who can invest in extensive equipment. The smaller operator has remained handicapped, and has been seeking methods involving lower capital outlay.

Recently, U.S.I. has been working with coke oven producers on the application of sodium desulfurization to this problem, with some very practical results. It has been found that, for only a little over a cent per gallon in treating costs, light oil feeds from coke oven sources can be purified to the desired levels. Further, this processing method is economical even for the small-scale producer.

Two U.S.I. Processes Available

Two general processes have been worked out by U.S.I. for the sodium desulfurization of light oil feeds in the vapor phase. In one, a mechanically agitated high-surface-sodium bed is used. In the other, vapor fluidized high-surface-sodium is employed.

Many samples of light oil from various parts of the country have been investigated in pilot units of these two types at U.S.I.'s research laboratories. The results of three such investigations, with calculated direct operating costs, are given in the

MORE

PILOT PLANT DATA—SODIUM DESULFURIZATION TEST RUNS

Acid-Washed BTX Sample	Process	Temp.	Na Level ¢/gal. feed	Contact time, sec.	Orig. thiophene content ppm	Final thiophene content ppm	Cost of treatment ¢/gal.*
A	Mechanically Agitated Reactor	450–500°F	.025¢/gal.	10 sec.	45 ppm	less than 1 ppm	1.4¢/gal.
B	Fluidized Bed Reactor	450–500°F	.013¢/gal.	10 sec.	1,000 ppm	less than 1 ppm	1.1¢/gal.
C	Agitated Reactor	450–500°F	.01¢/gal.	10 sec.	170 ppm	less than 1 ppm	1.7¢/gal.

* These are total calculated operating costs—including raw materials, utilities, labor and maintenance—for 3 different locations and different capacities. Cost figures are therefore not comparable.

National Distillers—Food Machinery Joint Venture Gets Rocket Fuel Contract

Contracts for multi-million pound quantities of unsymmetrical dimethylhydrazine have been awarded by the Air Force Air Material Command to a joint venture of the Food Machinery and Chemical Corp. and the U.S.I. division of National Distillers. These contracts total more than $20,000,000. The material, called DIMAZINE* by the joint venture, is a storable, high-energy liquid rocket fuel.

FMC and U.S.I. pioneered in the commercial development of unsymmetrical dimethylhydrazine, and have been its principal producers for several years. The Air Force's DIMAZINE requirements will be produced in expanded facilities at Baltimore, Md.

DIMAZINE is a completely synthetic fuel. It is used with liquid oxidants in bi-propellant engines of the type that power most of this country's large rocket vehicles as well as various smaller ones. Unsymmetrical dimethylhydrazine is unique in being the only synthetic fuel used in a substantial number and variety of the nation's operational rocket programs for scientific and military purposes.

*Registered Trademark of Food Machinery and Chemical Corp.

CONTINUED

Sodium Desulfurization

accompanying table. These figures are for BTX mixtures. The same processes can be used to treat benzene-toluene, benzene alone, or toluene alone — at still lower operating costs.

Distillation Removes Many Impurities

While the whole crude light oil may be desulfurized with sodium, distillation prior to sodium treatment is a more economical method for removing many of the sulfur compounds and other impurities present. Thiophene, of course, cannot be removed economically by distillation. An acid wash prior to sodium treatment is also used frequently to lower the level of some impurities.

Since purity requirements are usually less critical for xylene than for benzene and toluene, it is generally considered preferable to separate xylene from BTX mixtures before sodium refining. This minimizes sodium consumption. If necessary, xylene can be purified by itself.

For further information, send for the new U.S.I. technical data bulletin "Desulfurization of Benzene, Toluene and Xylene by Sodium." Address Technical Literature Department, U.S.I. Chemical News, 99 Park Avenue, New York 16, New York.

For commercial-scale processes developed by U.S.I., and for their costs, U.S.I. can put interested parties in touch with engineering companies who have developed plant designs for these processes.

Process Good for Many Hydrocarbons

Sodium desulfurization has also been used successfully with other hydrocarbons such as naphthalene. U.S.I. researchers have broad experience with this process, and will be glad to work with interested companies.

New Extinguisher Quenches Three Types of Fires

For the first time in history, a fire extinguisher has been developed which will put out all types of fires, according to recent reports. The extinguisher is said to do an effective job of quenching the three principal kinds of fires—those in combustibles like paper and wood, those involving flammable liquids like gasoline, and those in electrical equipment.

It uses a non-caking and moisture-repellent dry chemical which expands into a rubbery mass when exposed to heat. This action tends to smother the fire.

Up to this time the many kinds of fire extinguishers have been able to handle one, and sometimes two, classes of fires, but never all three. While the new extinguisher is claimed effective on all three, it does not supplant other extinguishers which may have superior quenching powers on a particular type of fire.

Rapid Chemical Reactions Analyzed by Photoflash

By exposing various materials to billion-watt flashes of light that last only a millionth of a second, chemists have recently observed many of the short-lived substances that play key roles in photochemistry, it is reported. Called "flash photolysis," the new analytical technique has already revealed the details of important chemical processes in areas ranging from inorganic chemistry to biology.

The technique employs a microsecond flash of strong light to start the reaction. Then, after an interval of a hundred thousandth of a second or less, the mixture is analyzed spectroscopically by a fainter burst of light. In this way, intermediate products with a lifetime of only a few millionths of a second have been positively identified, according to the report.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing U.S.I.

Patented process for making organic microfibers now being licensed. In process, vinyls, acrylics, nylon, polyesters, asphalt, etc., are melted or dissolved and sprayed to form superfine fibers. Suggested for filters, other uses. **No. 1620**

Variable programming systems, for automation of chemical analyses and procedures in clinical and biochemistry, now on market. Units include indexing, transfer, storage, centrifuging, incubating, programming mechanisms. **No. 1621**

Corporate diagrams and administrative personnel of the chemical industry are presented in new, looseleaf edition of reference book now being sold. Supplement also supplied to keep information up-to-date. **No. 1622**

Counter-current, liquid-liquid extractors for complex solvent extraction are described in new bulletin now available. Extractors incorporate several mixing and separating stages in single bowl revolving at high speed. **No. 1623**

How ammonium nitrate behaves under fire conditions is covered in new article which can now be purchased at nominal price. Conditions necessary for explosion are detailed, as are fire-fighting procedures and storage methods. **No. 1624**

POLYMER, a new international quarterly devoted to science of large molecules, is now offered on paid subscription basis. Provides medium for publication of original papers on chemistry, physics, applications of polymer research. Includes publicity on papers to come. **No. 1625**

Technique for producing flame-resistant urethane foam of polyester type is described in new bulletin now available. Reveals that additions of tris (beta-chloroethyl) phosphate (TCEP) to foam mix controls burning rate. **No. 1626**

New, low-cost infrared spectrophotometer makes possible high-resolution runs in near-infrared wavelength region between 83u and 7.65u. Gives exact structural information on organics with C-O and O-H molecular configurations. **No. 1627**

Alkaline electrocleaner, containing chelating agents, has been introduced for heavy-duty anodic cleaning of heavily soiled steel which has enough smut, rust or oxides to defy complete cleaning in conventional electrocleaners. **No. 1628**

Tantalum and niobium metallurgy are subject of recent book which can now be purchased. Covers extraction, reduction, consolidation, working. Includes chapters on physical, chemical, mechanical properties; corrosion; alloys. **No. 1629**

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Competition abroad– a time for reappraisal

THERE ARE A RAPIDLY increasing number of U. S. firms that are voicing their objections to trying to make friends by converting militarily weak nations into strong industrial competitors. At the conclusion of more than a decade of devoted giving, our military allies have become business competitors. These allies have become such potent competitors in the chemical industry that some concerns are at the point of taking positive, perhaps drastic, action.

Recently many producers of industrial products and equipment, like the chemical industry, have begun to make their wishes and needs in connection with "unfair" foreign competition forcefully known. O. R. Strackbein, Chairman, the Nation-Wide Committee on Import-Export Policy, An Association of Industry, Agriculture and Labor, on July 20, 1960 cited the record of the Tariff Commission for the past eighteen months, saying that out of a dozen cases of industries seeking redress from import injury, only one was forwarded to the President with a recommendation that the duty be increased. This was a minor case involving typewriter ribbon cloth.

Two chemical producers have just sent emissaries abroad, a third is ready to leave and a fourth is making preparations to go. Reportedly their assignments are to get facts and to make known their intention to meet "fire with fire". But, even in these instances, one may be sure that all efforts to have the U. S. Government utilize its resources to provide relief will be sought before direct individual solutions to the problem are attempted. All types of assistance to underprivileged nations and certain special help to highly industrialized nations seem to be generally acceptable to all U. S. political factions. But there is a considerable difference of opinion on the extent to which we should burden the taxpayer to contribute to these admittedly worthy causes.

Washington is becoming deeply conscious of the need to carefully choose the form of assistance we offer. One Washington source, well versed in the chemical industries' international problems, feels that we would do

continued on page 22

Acid-proof answer to your valve problems...

Lapp PORCELAIN VALVES!

THERE *are* no valve corrosion problems when you install Lapp porcelain valves on your chemical lines. Only porcelain and Teflon packing comes in contact with fluid being handled. And Lapp special porcelain is hard, dense and pure . . . homogeneous, non-porous and chemically inert . . . therefore impervious to corrosion from acids of all concentrations, except hydrofluoric.

WRITE on your letterhead for Catalog 567. It will put complete information on chemical porcelain at your fingertips. Lapp Insulator Co. Inc., Process Equipment Division, 2008 Poplar Street, LeRoy, N. Y.

3 BASIC TYPES MEET VARIED REQUIREMENTS

UNARMORED—Valve body of white glazed porcelain. Maximum recommended temperature, 350° F.

TUFCLAD® ARMORED—Porcelain body with exclusive Lapp armor casing of resin bonded fiberglass...for applications where accidental damage of porcelain becomes an immediate hazard to personnel or product. Maximum temperature, 225° F.

ALUMINUM ARMORED—Recommended where armoring is needed and service temperature exceeds that of Tufclad. High strength silicon aluminum casting is cemented over porcelain body. Maximum temperature, 400° F.

All valve types are proof-tested leak free at 150 psig. —recommended for operation at 80 psig.

Lapp

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Maintain
Coating Application
Standards

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HOLIDAY DETECTOR!

- Locates Skips & Holidays!
- Insures Complete Coverage!
- Insures Complete Protection at Critical Welds & Corners!

A tiny pinhole "holiday" in the protective coating allows a foothold for corrosion to undercut the coating. Progressive corrosion follows with peeling, scaling and ultimate failure.

You can't see these deadly "holidays," they become visible only when it's too late.

The M-1 TR Holiday Detector accurately and quickly finds pinholes and bare spots in thin film protective coatings. In operation an electrode is passed over the surface. On encountering a void or bare spot, a small current flows and a bell rings. Maximum applied voltage is 67½ V.

Different models of TR Holiday Detectors are available for pipe or flat surfaces, damp or dry surfaces and for portable or production line operation.

Engineering Note:
To insure a perfect application, your specifications should include TR holiday detector inspection. Write for specification guide.

Write today for technical data and bulletin.

Quality Control for Coating Application

TR TINKER & RASOR

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For more information, turn to Data Service card, circle No. 21

Washington scope

from page 21

well to more meticulously investigate the domestic needs of each foreign country allegedly needing help, so we will not unwittingly create competition we cannot meet either in the world market or here in the United States. This source suggested that bicycle factories are often really more essential to the foreign countries' economy than are chemical plants. Furthermore, there are process plants —like saline water conversion plants and food processing plants—that produce needed products which do not lend themselves to export, they contend.

Foreign jobs with built-ins

The Federal Government has already initiated an arragement for getting more "missionaries for democracy" abroad. Public Law 86-585, just signed by the President, is designed to make foreign assignments more appealing to its employees. The new law virtually guarantees employees returning from foreign duty that they will have their old jobs back if they want them. It is anticipated that there will be a big jump in overseas assignments.

"There seems to be no abatement in our zeal to help our foreign allies stay economically strong by enabling them to compete with us on a world-wide basis. This really makes it tough on those who don't have facilities abroad", is typical of the comments one hears from the men who keep a watchful eye on world-wide chemical industry developments.

—Jos. L. Gillman, Jr.

An 80 million pound-per-year ethylene oxide plant, one of the largest units of its kind ever constructed, will be designed and built for Houston Chemical by Scientific Design. The Beaumont, Texas, plant anticipates an 800-tons-a-day nitrogen by-product available for ammonia production. The glycol output will go into Houston Chemical's antifreeze, tradenamed Peak.

More news on the nylon front: a new fine denier Caprolan nylon yarn plant at Irmo, S.C., will increase Allied Chemicals overall nylon fiber capacity to more than 80 million pounds a year. Technical assistance and some manufacturing equipment will be furnished to Allied by Snia Viscosa, Italian fiber producing firm.

Engineering Progress Report
FROM UNION CARBIDE CHEMICALS COMPANY

Acetonitrile boosts butylene throughput 58%, saves $3,000,000 capital investment

Unusual solvent useful in saturate-unsaturate and olefin-diolefin separations

By using acetonitrile as an extractive distillation solvent, Shell Chemical Corporation has boosted throughput of the existing butadiene feed-preparation unit 58% in their Torrance plant. Minor engineering changes for the unit cost $148,000; it has been estimated that a similar throughput increase through new construction would cost about $3,000,000. Development work and operating experience have shown that acetonitrile's unusual solvent properties should prove useful in other saturate-unsaturate and olefin-diolefin separation processes.

ADVANTAGES OF ACETONITRILE

Acetonitrile has boosted capacity in the Shell plant because it increases the spread in boiling points of the C_4 hydrocarbons being distilled. Thus, separation of the hydrocarbons is more efficient than with either acetone or furfural. Relative volatility of n-butane compared to butene-1 is about 1.25 with acetone and about 1.30 with furfural. Acetonitrile increases this ratio to almost 1.4. The spread in boiling points of butene-1 and butadiene is also increased. The table gives data on the relative volatilities of C_4 hydrocarbons in aqueous acetonitrile systems.

After the extractive distillation has been completed, acetonitrile can be completely recovered from the butane and butylene streams with greater ease than acetone. This increased recovery efficiency is due to the high distribution coefficient of acetonitrile in water/hydrocarbon systems.

ENGINEERING CHANGES MINOR

Because of the similarity of the physical properties of acetonitrile and acetone, it is not necessary to change the operating pressure of extractive distillation columns. Shell engineers made only minor changes to their unit. Besides a larger reboiler and a new pump, two heat exchangers were switched and the solvent recovery column was connected to vacuum operation. Aqueous acetonitrile systems do not foul exchanger systems. Corrosion due to hydrolysis of solvent at reboiler temperatures is minimized by pH control.

TABLE 1 RELATIVE VOLATILITIES OF THE C_4 HYDROCARBONS IN AQUEOUS ACETONITRILE, 120 psia

Component	Total Solvent Concentration, 80%m		Total Solvent Concentration, 85%m	
	Water in Solvent 15%m	Water in Solvent 25%m	Water in Solvent 15%m	Water in Solvent 25%m
Isobutane	1.638	1.673	1.637	1.674
n-Butane	1.332	1.347	1.348	1.368
Isobutylene	1.013	1.013	1.013	1.013
Butene-1	**1.000**	**1.000**	**1.000**	**1.000**
t-Butene-2	0.861	0.856	0.865	0.861
cis-Butene-2	0.821	0.813	0.827	0.820
Butadiene-1, 3	0.639	0.599	0.645	0.604
Water	0.08	0.045	0.075	0.045
Acetonitrile	0.043	0.033	0.043	0.033

OPERATING COST REDUCTIONS

The butadiene feed-preparation unit operating on acetonitrile has less solvent-loss than one operating on acetone. *Thus, solvent make-up costs are no higher with acetonitrile than with acetone.* Steam and pumping costs have also been reduced because reflux and circulation rates are lower. This is true even at reduced feed rates.

ACETONITRILE USEFUL IN OTHER PROCESSES

Acetonitrile is effective in other saturate-unsaturate and olefin-diolefin separations. This heat-stable extractant is useful in ethylene-ethane, propylene-propane, and cyclopentadiene-cyclopentane separations. The boiling point spreads between pentadienes, such as isoprene, and pentenes are also increased.

In liquid-liquid extraction processes, acetonitrile is effective in removing tars, phenols, and color bodies from hydrocarbons. Acetonitrile is also useful as a selective solvent for fatty acids.

INFORMATION AVAILABLE

If you're looking for increased efficiency in your extractive distillation or liquid-liquid extraction processes, acetonitrile could be the answer. Detailed information on acetonitrile as an extractive distillation solvent along with information on azeotropic mixtures of acetonitrile is available. For this information, call the nearest CARBIDE Technical Representative—or write, Department B, Union Carbide Chemicals Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, New York.

Nothing herein shall constitute a recommendation to practice any invention covered by any patent without permission of the patent owner.

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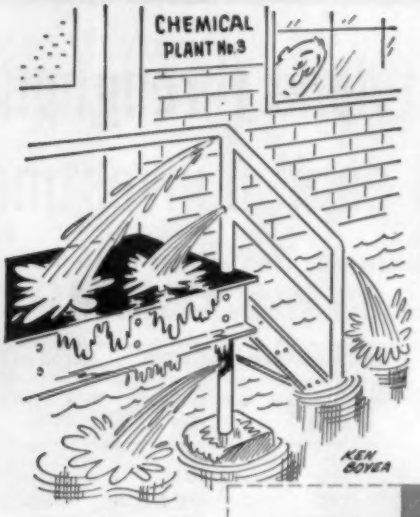
For more information, turn to Data Service card, circle No. 77

Life in these excited states...



Corrosion is full of surprises

Out-guessing corrosion has been our business for 100 years. We now make 8 types of chemical resistant pipe . . . with valves, pumps, and tanks to match . . . and pretty well know what to expect with them. If anything, our advice is on the *safe* side. Please consult us with *any* problem.

All-purpose rigid PVC. Sched. 40, 80 & 120, ½ to 4". Threaded or socket-weld fittings. Valves ½ to 2". NSF-approved. *Bul. CE-56.*

Improved design . . . now 12 gpm. All wetted parts acid-resistant, wear-resistant Ace hard rubber. Finest available. *Bul. CE-55.*

Flexible poly pipe, ideal for water lines, drains, underground pipe or conduit. Sizes ½ to 2", long coils, NSF-approved for drinking water. *Bul. CE-57.*

World's best chemical valves . . . at moderate prices. All-plastic, rubber-lined, or all-hard-rubber. ⅛" pet cocks to 24" gate valves.

ACE *chemical resistant equipment*
BY AMERICAN HARD RUBBER COMPANY
DIVISION OF AMERACE CORPORATION
ACE ROAD • BUTLER, N.J.

See ACE equipment in Chemical Engineering Catalog

For more information, turn to Data Service card. Circle No. 11

letters to the editor

Chem Econ Handbook

To the Editor:

We appreciated seeing the reference to our *Chemical Economics Handbook Revision Supplement* on page 12 of your June, 1960, issue. We would like to point out, however, that this supplement is available only to *Chemical Economics Handbook* subscribers.

If it is within your editorial policy, we would very much appreciate your rerunning the notice and indicating this limitation on its availability.

ROBERT W. TAYLOR

Stanford Research Institute
Menlo Park, Calif.

Readers interested in subscribing to the excellent handbook published by SRI can contact them directly—ED.

More research and training

To the Editor

The recent trend of decline of engineering has been repeatedly discussed in *Chemical Engineering Progress* (Opinions and Comments, Nov. 1959, Jan. & Apr. 1960). You have also mentioned (April 1960) that not enough was said on what to do about it. Presumably you are particularly concerned with chemical engineering. As a former chemical engineer, may I venture a guess?

High school students are shying away from chemical engineering because of lack of publicity, people at M.S., B.S., or college undergraduate level are leaving because of lack of specialization and lack of inspiring research. Chemical engineering is composed of physical chemistry, applied mathematics, engineering mechanics, mechanical engineering, electrical engineering, etc., a little bit of each, but never much of any one thing. Hence the average chemical engineer is quite handicapped in competing with any specialist; for example, an aerodynamicist will be much better qualified than a chemical engineer in solving fluid mechanics problems. Many research works have been fancy but useless. Usually equations are set up according to "recipes" (for example, heat transferred "must" be proportional to temperature gradient) and

continued on page 28

MERCOID

316 STAINLESS STEEL BOURDON TUBE

PRESSURE CONTROLS

316 Stainless Bourdon Tube

316 Stainless Pressure Connection

Nickel Plated Mechanism

SERIES D-41, D-541, D-243

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- EXPLOSION-PROOF NEMA 7, 9, 9A
- WRITE FOR BULLETIN 019

MERCOID CONTROL

THE MERCOID CORPORATION

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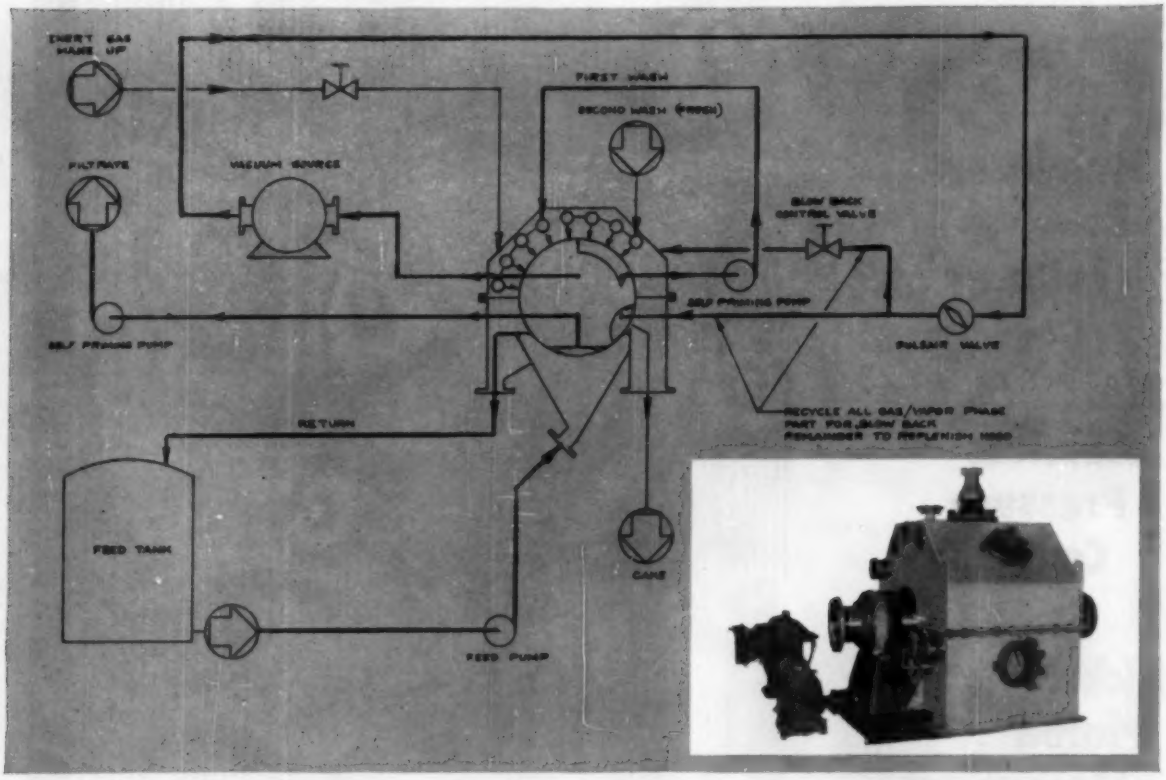
For more information, turn to Data Service card, circle No. 10

One Look at this Flow Sheet Tells You That the BIRD-YOUNG Vacuum Filter Is the One for Fume-Tight Operation



The Bird-Young Filter's unique design and simplicity of construction readily permit totally enclosed, tightly sealed operation. Exhausted air or vapor is subject to return so that pressure is always balanced and loss or expensive recovery of volatile solvents is avoided.

Before you buy a vacuum filter, look into the Bird-Young. The Bird Research and Development Center is well equipped to give you a look at actual performance facts and figures in advance of your investment.

Other advantages of Bird-Young design include:

- **high throughput of solids per foot of filter area** which often means fewer or smaller units
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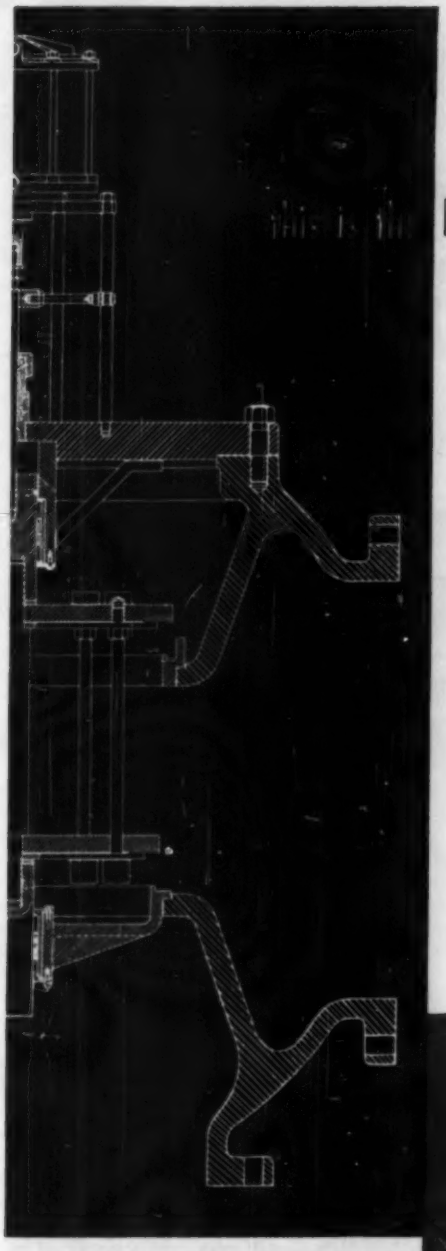

this is the largest double-seated control valve ever made

When you are talking *big* control valves, talk to Kieley & Mueller. K&M is the largest manufacturer of the big ones, control valves above 16 inches. Standard globe-type valves are available in 20, 24, 30 and 36 inch sizes; even larger valves will be produced on special order.

This 36-inch double-seated angle valve closes snugly on giant Teflon seats. The inner valve positions responsively, gliding on special roller-slide bearings. It's massive, but is operates protected by a K&M patented torque resistor. Beyond the problem of size, this valve is mounted on its side, and it has been performing creditably for over four years.

BIG or small, if it's control valves, you'll like the pitch-in, helpful approach of your local K&M representative . . . plus capable engineering and manufacturing follow-thru at the K&M plant.

Write for Bulletin CV-53.

ABOVE: Partial cross-section of K&M 36-inch valve showing general construction.

AT RIGHT: Actual size of a 36 inch valve can be visualized from this illustration of a workman inside the valve body performing finishing operations.

K&M

KIELEY & MUELLER, INC.

78th Anniversary . . . Oldest U.S. Pressure and Level Control Valve Manufacturer

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F[illegible]PARTICLES
L[illegible]AINTENANCE

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"Jet-O-Mizing" produces **FINE PARTICLES** ¼ micron average and above **PLUS . . .** Narrow Particle Distribution • Dry, or Controlled Moisture Content • Continuous Operation • Uniformity of End Product • Other Operations with Grinding • No Attritional Heat — No Moving Parts • Low Operating Costs • Low Maintenance

Send for complete information on Fluid Energy's "Jet-O-Mizer" Mills, "Jet-O-Clone" Dust Collectors, and TESTING AND CUSTOM GRINDING services.

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(Formerly known as the Wheeler-Stephanoff Mill)

For more information, turn to Data Service card, circle No. 20

Letters to the editor

from page 24

then solved by computers. Compared to laws in physics, such as Newton's law of gravitation or the Pauli exclusion principle, many concepts in chemical engineering are, at best, approximate in nature. Accuracy of chemical engineering experimental data is usually poor. The phenomenological nature of chemical engineering studies requires many parameters. Hence these calculations cannot be justified over an order of magnitude estimate either theoretically or experimentally. In other words, the aim has been the strengthening of the strongest (also the easiest one to get at) link in the chain, whereas the weaker links (validity of assumptions required to set up the equations, accuracy of experimental data, etc.) remain untouched. This lack of inspiring research has cast some doubts about chemical engineering among scientists and engineers. The subject of chemical engineering is also either omitted or de-emphasized at a number of major universities (for example, Harvard and Chicago).

Little can be done about lack of publicity. Scientific achievements are the best publicity agents of science. Works of Fermi and Einstein (more recently, Yang, Lee and parity) have publicized physics enormously. So are J. Willard Gibbs, G. N. Lewis and chemistry. However, among the best engineers (such as Theodore von Karmen, Geoffrey Taylor, Stephen Timoschenko), few can be classified as chemical engineers. Also, there seems to be no Fermi or Einstein among the chemical engineers in the near future. It is therefore questionable how chemical engineering can be publicized.

However, teaching and research in chemical engineering can be improved, and ought to be. More fundamental work, replacement of ponderous calculations by simpler methods, improvement in unit operations courses (removal of technical jargon, emphasis on fundamentals rather than applications of nomographs or empirical design equations) and more specialization in training all seem to be necessary.

It seems that chemical engineers must improve both their research and training, or their future will be limited to industrial production and development work only.

TUNG TSANG
Department of Chemistry
University of Chicago

For more information, circle No 55

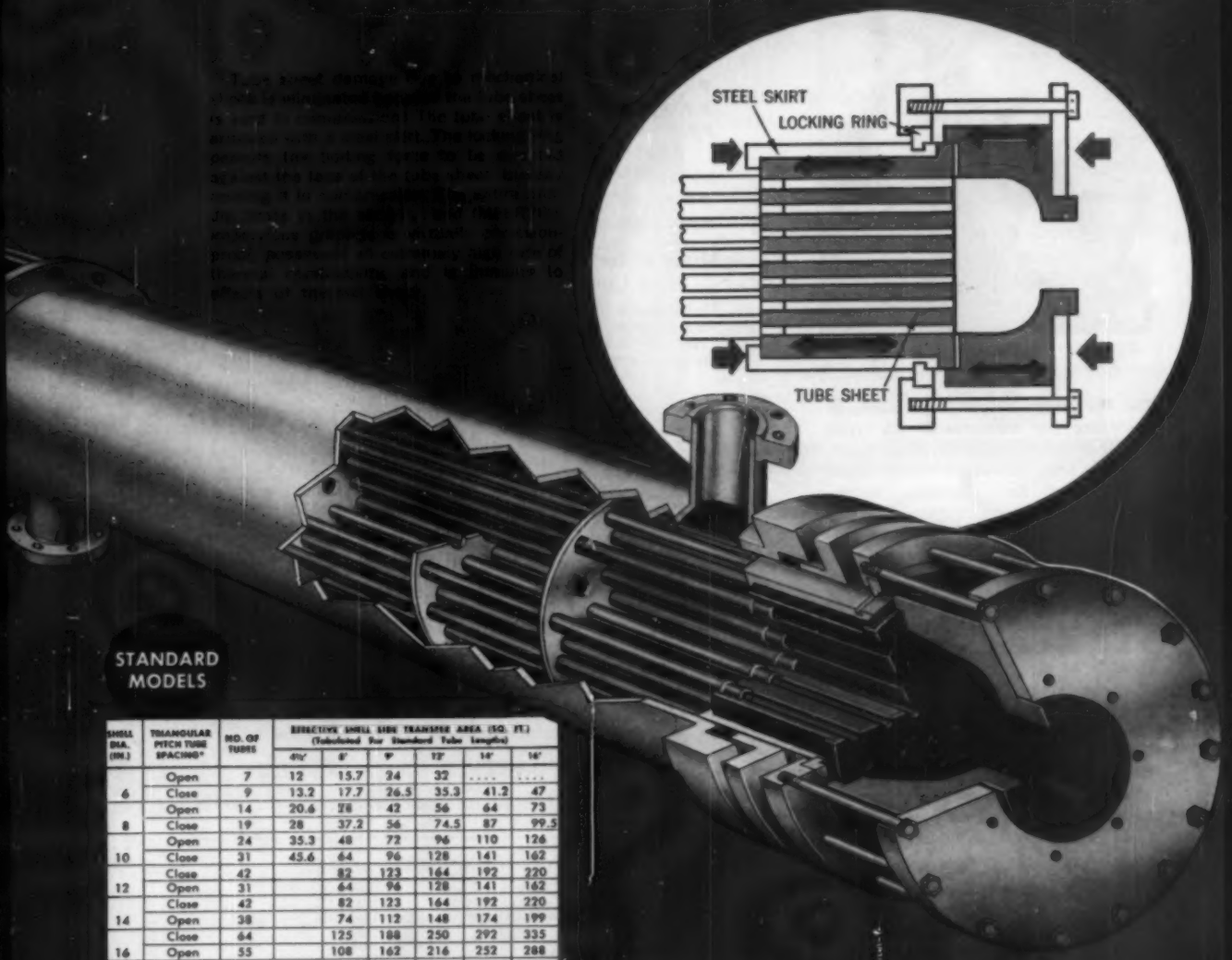
Only FALLS INDUSTRIES

IMPERVIOUS GRAPHITE

Tube and Shell Exchangers

feature

COMPRESSION HEAD DESIGN



STANDARD MODELS

SHELL DIA. (IN.)	TRIANGULAR PITCH TUBE SPACING*	NO. OF TUBES	EFFECTIVE SHELL SIDE TRANSFER AREA (SQ. FT.) (Tabulated For Standard Tube Lengths)					
			4½'	8'	9'	12'	14'	16'
6	Open	7	12	15.7	24	32	....	....
	Close	9	13.2	17.7	26.5	35.3	41.2	47
8	Open	14	20.6	28	42	56	64	73
	Close	19	28	37.2	56	74.5	87	99.5
10	Open	24	35.3	48	72	96	110	126
	Close	31	45.6	64	96	128	141	162
12	Close	42		82	123	164	192	220
	Open	31		64	96	128	141	162
14	Close	42		82	123	164	192	220
	Open	38		74	112	148	174	199
16	Close	64		125	188	250	292	335
	Open	55		108	162	216	252	288
18	Close	85		166	250	332	388	445
	Open	74		145	218	290	339	387
20	Close	109		214	320	427	500	570
	Open	92		180	270	360	420	481
22	Close	130		255	383	510	595	680
	Open	121		236	356	472	554	634
24	Close	163		320	480	640	745	850
	Open	151		296	444	592	690	790
26	Close	197		386	580	772	900	1030
	Open	170		333	500	666	778	890
28	Close	235		460	690	920	1070	1230
	Open	206		405	606	810	945	1075
30	Close	268		525	790	1050	1230	1400
	Open	241		472	710	944	1100	1260
34	Close	349		685	1025	1370	1600	1830
	Open	316		620	930	1240	1445	1650
38	Close	439		860	1290	1720	2010	2300
	Open	403		802	1200	1600	1845	2140

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The development of instruments capable of detecting trace quantities of gases in the atmosphere, or other gas backgrounds has necessarily demanded mixtures of ever increasing complexity and accuracy, and has made necessary a continuing program of research to provide the standards for calibration required by these new tools of the chemical industry.

Whether your requirement be for a sterilizing gas capable of extreme penetration, a radioactive gas mixture for tracer studies, or a controlled biological atmosphere, Matheson's broad background of gas technology can provide the high quality gas mixture for your application.

A typical listing of the mixtures prepared in our mixture department appears at the right.

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p.p.m.—99.6%	Oxygen in Nitrogen (Prepurified)
p.p.m.—40%	Carbon Dioxide in Nitrogen (Extra Dry)
p.p.m.—40%	Carbon Dioxide in Air (Dry)
p.p.m.—10%	Carbon Monoxide (C.P.) in Nitrogen (Prepurified)
p.p.m.—0.5%	Carbon Monoxide (C.P.) in Air (Dry)
0.5-99.8%	Hydrogen (Electrolytic) in Nitrogen (Extra Dry)
p.p.m.—0.5%	Hydrogen (Prepurified) in Nitrogen (Prepurified)
p.p.m.—10%	Methane (C.P.) in Nitrogen (Prepurified)
p.p.m.—3.0%	Hexane in Nitrogen (Prepurified)

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90-100% Nitrogen (Prepurified)

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0.5-10% { Carbon Dioxide in Air (Dry) / Carbon Dioxide in Nitrogen (Extra Dry) / Carbon Dioxide in Oxygen (Extra Dry) }

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☐ Wall Chart: "Safe Handling of Compressed Gases"
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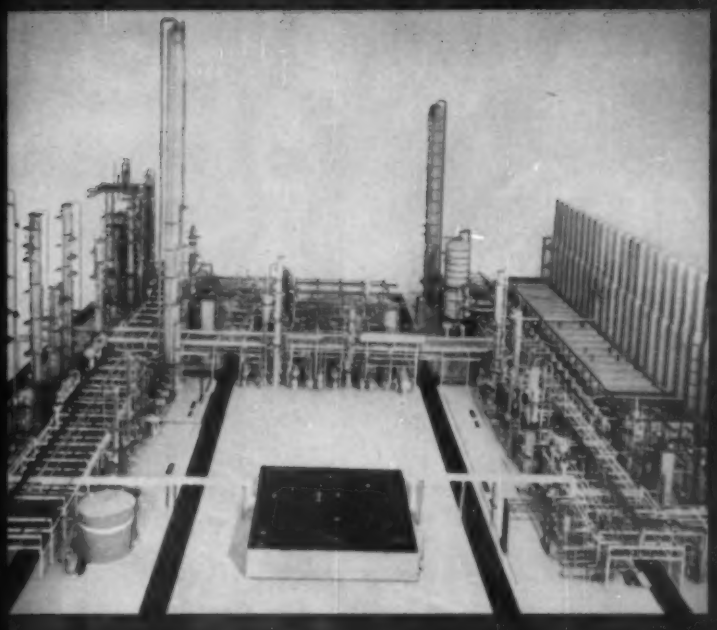
For more information, turn to Data Service card, Circle No. 85

For more information, circle No. 16 ▶

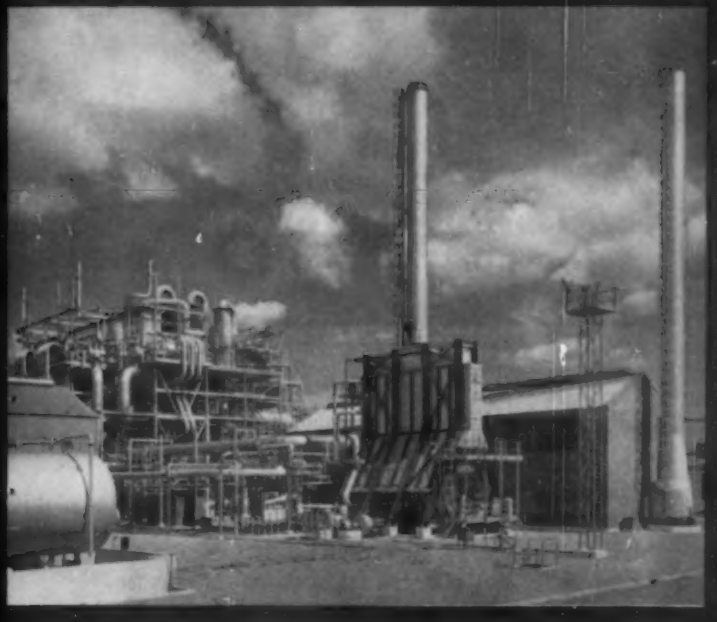
Kellogg Engineers and Builds World's Biggest Olefin Plants



Mobil

FUTURE WORLD'S LARGEST is Socony Mobil Oil Company's ethylene plant at Beaumont, Texas. It is the first large plant in the U.S. to crack naphtha into olefins. Engineered by The M. W. Kellogg Company, as shown in this scale model, it is scheduled for completion by Kellogg by 1961. Capacity will be 380 million pounds annually of 99.9% purity ethylene.

This newest plant consists of steam pyrolysis, gas treating, and product recovery sections. It has been designed to handle simultaneously both liquid and gaseous feedstocks. In addition to ethylene, major products will include propylene, propane, a B-B product, gasoline, and fuel oil.



ICI

LARGEST OUTSIDE THE U.S. is the English Wilton Works of Imperial Chemical Industries, which now includes three olefin plants. Photograph shows Plant No. 3. All are the result of close engineering cooperation between Kellogg and I.C.I. Together, they represent a current output of 110,000 tons per year of high-purity ethylene, and a potential of 140,000 tons.

Plant No. 1, commissioned in 1951, was the first full-scale adoption of the then novel process of oil pyrolysis developed in Kellogg's laboratories. Its success led to the addition of Plant No. 2 in 1956, and then to No. 3—representing a 60% increase in olefin capacity—in 1959.

Whether your approach to ethylene is through the steam pyrolysis of hydrocarbons or the recovery of ethylene from gas mixtures, Kellogg has developed processes which can assure the optimum investment, operating costs, product purity, and yield. For more information about Kellogg's 2-billion-pound background in engineering and/or building ethylene plants, write for a copy of "Olefin Plants" Kelloggram.

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Take a look at the "works" of a MIKRO-PULVERIZER, and you'll have a pretty good idea why these units have been receiving the nod of approval from the processing industries for so many years. It's not just a "grinder" . . . but a precision-engineered unit in which each component is carefuly machined and balanced, held to close, uniform tolerances. And this is true of the entire MIKRO-PULVERIZER line, from the smallest pilot plant mill to units producing upwards of ten tons per hour! You'll find the Mikro Laboratories at your disposal, ready to test grind your product and help you select the unit for your particular requirements. As an additional assurance, we're set up to ship genuine Mikro replacement parts to you within 48 hours of order. Bulletin 51A has the full story of models and capacities. It's yours for the asking, with no obligation.

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MANUFACTURING FACILITIES: United States, Canada, Continental Europe, British Isles.

For more information, turn to Data Service card, circle No. 33

Weather isn't immune to modification

THE OLD SAW ABOUT EVERYONE talking about the weather but no one doing anything about it has about run its course. Eight federal agencies, more than a dozen States, and about two dozen independent groups are involved in meteorological and cloud and weather modification activities. Basic studies underway, while growing in number, are of necessity moving slowly. Weather is not something you can simply cork up in a flask and research in a comfortable lab. Nevertheless, progress is being made. Conceivably, alteration of local and regional weather patterns could affect selection of future plant sites, notably in regions deficient in water and power.

Medicine man, go home

The National Science Foundation is presently sponsoring a million-dollar-plus program for study, research, and evaluation in the field of weather modification. Research in the main will be characterized by its long-range fundamental approach, and practical results shouldn't be anticipated until basic data have been accumulated and analyzed. This is, as it should be, a far cry from some of the latter-day charlatans who promised to solve drought-stricken communities' water problems overnight. Like the rainmakers of earlier days, the many amatuerish efforts simply compounded the confusion. A battery of criticism from members of the scientific community resulted in demands for a sound experimental approach. An outgrowth of this was the NSF program.

In its first annual report on the subject of weather modification, the NSF has brought into focus progress being made by other groups as well as itself. And in reviewing the overall picture has highlighted some interesting findings.

Arizona U. investigators, for instance, found that mean rainfall was approximately 30 per cent higher on seeded than on nonseeded days. Lightning flashes were about nine times more numerous on seeded days.

Cloud seeding in mountain areas of the Pacific coast result in measurable increases in precipitation, according to Chicago University experimenters. It's much harder to get results over the flat terrain of the Great Plains, and no positive results are forthcoming at this time.

Arthur D. Little, Inc., scientists are investigating the theory that cloud electrification may be largely a cause rather than a result of precipitation, as has been previously thought. The U. S. Weather Bureau has observed that a peak is reached in the number of freezing nuclei in clouds in widely separated locations about 30 days after meteor showers occur on the earth.

The Navy is supporting a study of freezing rain and the possibilities of modifying it to a less hazardous form of precipitation. It's also considering the possibility of a small rocket which could be launched by one man for seeding a specified cloud. The Air Force is working to figure out ways to disperse or prevent low clouds and fogs at airports.

The Interior Department has an especially interesting activity underway, dealing with evaporation modification. Monomolecular chemical films, spread over a water surface, can reduce evaporation. If practical on a large scale, local weather could be affected.

Dial W- for weather

The results of most of the studies and experiments indicate the need for fundamental research, and the NSF feels most field research projects should continue for 5-7 years to minimize annual variations. Despite the long-range aspects, there are glimmers which indicate a partial mastery of the weather is in the not-too-distant future. One report says cloud seeding in 11 Western states would up runoff by 15 million acre-feet annually. When problems are solved in the plains states, a much greater increase can be expected. Proper cloud seeding should result in more gentle rainfall, and less severe storms, lightning and hail. The real long-range picture involves meterological satellites and climate control on a continental scale. This, it goes without saying, lies within the realm of a remote possibility.

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opinion and comment

Whither engineering education?

NOTHING EVER STANDS STILL, including engineering education. It, like all things, must shift with the changing times to respond to the needs of today and tomorrow. But change is not necessarily totally beneficial, nor is it necessarily as rapid as it should be. These latter comments reflect statements made recently by two eminent academic officials.

There has been a shift away from the empirical towards the theoretical and abstract, says Julius A. Stratton, M.I.T. president, a change which is alarming. His concern is that in the process of assuring for the student a mastery of mathematical analysis there will be a failure in the equal development of his other powers of perception.

Despite all the current emphasis upon graduate research, there has been a steady decrease in the time exacted from an undergraduate in lab experiments and a more than compensating increase in hours devoted to theoretical discussions. Only through action and experiment does a student learn to observe. Analysis divorced from physical objectivity ultimately becomes barren, he continues.

It's a curious fact, says Stratton, that American mathematicians tend to be the most scornful of the potential usefulness of their labors. It is strange that, in light of our national heritage, the scholarly emphasis on physics is increasingly on the theoretical at the expense of the experimental. The power of logical analysis to abstract immensely complicated physical situations constitutes one of the supreme achievements of the human mind. But when abstraction becomes an end in itself, science and art invite sterility.

An almost arrogant intellectualism seems to affect a wide domain of American scholarship, according to Stratton. We must beware of immoderation in our approach to scholarship —of excesses that drain learning of its human content, and convey to the student merely an anemic image of the human drama, he says.

Engineers' new domain

The human aspect, meanwhile, is one which falls more and more into the domain of the engineer. As the world and our society becomes still more technologically complex, the greater will become the influence of the engineer in the shaping and direction of human affairs, says Dr. Robert F. Goheen, Princeton president. And there is a growing realization that the nature of engineering education must also change to accommodate new, intellectually rigorous demands. He raises four points, the first of which is somewhat contrary to his colleague's ideas.

1. The four undergraduate years should be pointed at the science of engineering, leaving training in skills and specialized technologies largely to industry.

2. Post-graduate education to doctoral level should, and will, receive increased emphasis, with engineers having to develop improved and expanded doctoral programs.

3. Engineers will be called upon for greater knowledge, understanding and concern about human affairs and human values than heretofore. More knowledge of humanities and sociopolitical affairs will be required.

4. The engineering profession must foster a truer understanding of science among laymen to avoid widening a breach between technical and non-technical groups.

Both gentlemen have made pointed and provocative statements, some or all of which will affect the future course of engineering education. Whither and how far it goes is far from a well-defined path.

L.R.

SOME FACTS AND FALLACIES ABOUT PACKED TOWERS

☑ **Packed towers are practical in diameters over 3 ft.**

TRUE. Modern tower packings, such as "Intalox"® saddles and metal Pall Rings have made an old "rule-of-thumb" obsolete. Formerly, engineers were hesitant to use packed towers over three feet in diameter, especially where distillation was involved. However, the high efficiencies and low pressure drops of these new packings have made large diameter towers a practical and economical mass transfer tool. We can cite distillation, absorption and even liquid-liquid extraction towers in successful operation whose diameters run 8 ft. or more.

☒ **Packed towers give higher pressure drops than tray columns.**

FALSE. Because of their low pressure drops, "Intalox" saddles and metal Pall Rings have found wide application in vacuum distillation. In these rather critical rectifications, metal Pall Rings, especially, have such low resistance that pot temperatures —and product pyrolysis—are maintained at a minimum. Moreover, these low pressure drop properties lead to smaller tower diameters with greater liquid irrigation densities and lower H.E.T.P.

☑ **Packed towers have lower first cost than tray towers.**

TRUE. Again, this is true because of the development in recent years of unique packing shapes. Their high capacity and greater mass transfer efficiencies permit the design of shorter and narrower columns, requiring smaller fluid moving equipment. Where corrosion is a factor, the low cost of chemically inert ceramic packings means impressive savings over the cost of special corrosion-resistant alloys.

☑ **Packed beds make efficient entrainment separators.**

TRUE. Mist elimination sections consisting of packed beds are used in commercial scrubbing equipment, even where the scrubbing sections themselves consist of trays. Moreover, the chemical engineering literature quotes many actual installations in sulphuric acid and other plants where satisfactory performance is being obtained from packed beds. Where fouling is a problem, the choice of the proper packing with a large interstitial free space, combined with adequate hydraulic radius, will prevent deposition of solids and thus maintain low pressure drop.

☒ **Performance of packed towers can't be predicted accurately.**

FALSE. Today packed tower performance can be predicted about as accurately as that of plate columns. That was not true, however, ten years ago. Accurate design data are multiplying rapidly as the use of packed columns continues to grow at a rapid pace. Extensive research being made in packed towers up to 30" in diameter is providing data that can be used to predict the performance of towers up to 25' or more with reasonable accuracy.

YES, *the introduction a few years ago of "Intalox" saddles, and, more recently, the metal Pall Ring, used with properly designed packed tower internals, has brought about a re-evaluation of methods used to effect mass transfer . . . have made yesterday's facts, today's fallacies. In new tower design, or to obtain greater capacity or better efficiency from present towers, it will pay you to investigate modern packed tower performance.*

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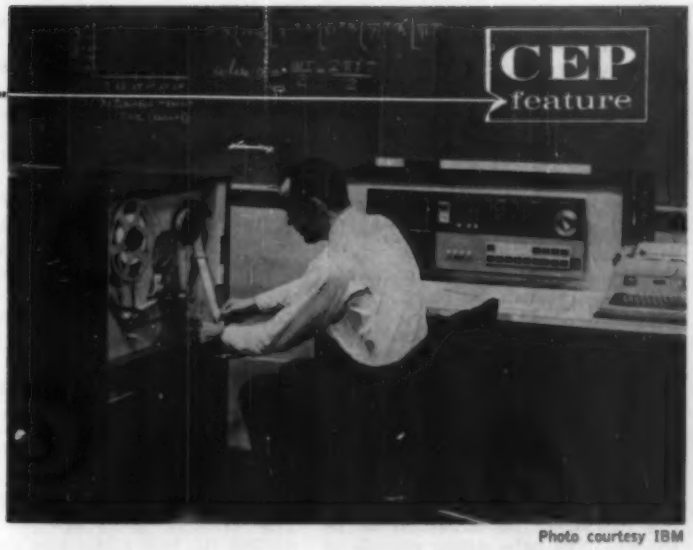

Photo courtesy IBM

Optimization in process equipment design

A critical survey of some methods and practices used for equipment design optimization with special emphasis on the use of digital computers.

Improved understanding of many engineering processes allows equipment performance prediction with unprecedented accuracy. This has been helped particularly by the availability of electronic computers which do not set the narrow limits to the intricacy of the mathematical models used. Intense competition in many fields lets even marginal savings in the operational cost appear more lucrative than they used to be. Consequently, if the specifications call for a plant of a certain capacity, the chances are, these days, that the management can get what it asks for with no (or much less) over-design safety factor included than was established practice in the past.

EQUIPMENT OPTIMIZATION LOGIC

Most problems of engineering equipment design have several if not, at least theoretically, an infinite number of solutions. The objective of optimization is to select, out of the multiplicity of potential solutions, the one which is best with respect to some desired property. While this variable can be any particular design parameter such as over-all size, ground space, weight, hold-up volume, etc., the most frequently encountered problem will be that of cost which will also be the basis for the following considerations.

Process operation economics

The general definition of the financial aspects of a process is that the profit P ($) is the difference between the value of the product V ($) and the cost of performing the operation C ($), or

$$P = V - C \qquad (1)$$

The cost of operation C can be broken down further to any desired detail. But two substantial groups can be distinguished: The fixed cost I ($), which includes the cost of initial installation and all factors depending on its value; the operating cost E ($), which includes all the cost components associated with running the facility, such as energy supply, regular and major maintenance, etc.

Consequently:

$$C = I + E \qquad (2)$$

The optimum design is one that will produce maximum profit. However, an optimum will not always exist. The optimum condition is such that one or more operational parameters can be varied within a sufficiently wide range to effect substantial changes in the equipment design and its cost; and at least two of the profit components V, I, and E will be affected by such variations in mutually opposite directions (i.e. one will increase while the other decreases) or, if changing in the same direction, their respective rate of change will be sufficiently different to produce an inflection point. Two typical examples can be given.

Example 1. The values of the product V and operation cost C are variable with an operational parameter p. This situation would apply to the design of a reactor where the operating pres-

sure is the variable. The product value will increase with pressure due to higher conversion, but so also will the cost of the apparatus and its operating cost. The rates of increase are, however, different and an optimum will exist at p_{opt}, Figure 1.

Example 2. In most cases of equipment design the result of the operation will be an intermediate product to which no value can be easily attached. In such cases V is constant, and an optimum design will be possible only if the component factors of the operational expenses I and E form a minimum total expense C, which will then be identical with maximum profit. A practical example of this case is the design of an optimum heat exchanger for specified duty and fixed temperatures. The heat exchanger is a part of a complex process and no value can reasonably be attributed to its function. The independent variable of optimization in this case is the fluid flow velocity. The higher the flow velocity, the smaller will be the required area and the fixed cost, but the higher will be the cost of producing the flow velocity required. The cost components I and E change magnitude in opposite directions thus fixing an optimum at p_{opt}, Figure 2.

Extent of process circuit

The extent of the process circuit which should be included in the optimization calculations commands particular interest. Whenever there is an operational parameter common to several units, the optimization should be carried out on the entire circuit involved. The extent of such calculations will frequently be prohibitive and simplified mathematical models for the individual units will have to be introduced. However, establishing the optimum with respect to the over-all process will bear much greater validity than the opposite process of optimizing the smaller circuits independently. The latter procedure will not necessarily lead to an over-all optimum.

Let us assume a relatively simple process as shown in Figure 3.

Cat cracker gas is fed to the first compressor stage, then through an intercooler where the liquefied portion is separated. The gas is further compressed in the second stage, cooled again, and fed to an absorber. The deeper we cool in the intercooler and the less pressure drop we require, the smaller will be the load on the second compressor stage due to lower temperature and smaller volume as a consequence of greater liquid separation. The performance of the aftercooler will, in turn, determine the design of the absorber.

The cooling water, itself, will form a separate economic circuit with the cooling towers and their accessories. The pressure drop of the water through the heat exchangers will constitute a third-degree optimization parameter.

All of these factors are interrelated and a rigidly-valid optimization is possible only if all of them will be considered simultaneously. While the given example is simple compared to actual cases, rigorous optimization would require a considerable number of calculations (probably beyond our present capabilities) and simplifications would have to be introduced.

The decision as to how large a circuit should be considered will be made for each individual case, based on the estimated sensitivity of the over-all cost to variations in the operating parameter and will be also governed by the feasibility of numerical execution.

OPTIMIZATION METHODS

Having defined the basic economic equations for the circuit subject to optimization, there are several methods available for establishing the optimum values of the design parameters.

Analytical solution

Analytical methods connote purely mathematical operations.

Classical method. The method is based on the mathematical theorem that equating the first differential of a function to zero and solving for the variable will deliver the position of the peak.

Optimization by this classical method is possible in all such cases where we deal with continuous parameters and equations, which in their differentiated form allow explicit solution for the optimization parameter. Unfortunately for engineering equipment designs these conditions apply only in exceptional cases. Nevertheless, several analytical optimization solutions for equipment design have been worked out, especially in the heat transfer field (*1-5*). These were possible only after the introduction of more-or-less bold simplifications (e.g. cost of heat exchangers assumed proportional to area).

For these reasons, optimization of equipment design by analytical methods has been used predominantly to only demonstrate the effects of opimization parameters on typical examples and to establish generalized design rules. In many cases this leads to practical and useful design methods but the user should be aware of the conditions restricting the validity of such developments.

Problems containing restrictions. Most engineering equipment is subject to a number of dimensional or operational restrictions derived from commercial availability, standard-size series, manufacturing practices, or process limitations. To deal with cases where restrictions are imposed, we have available a modification of the classical analytical method,[1] in which use is made of Lagrange's undetermined multipliers. Any arbitrary number of restrictions can be imposed, but the mathematical complications rise rapidly and the use of digital computers will be necessary for all but simplest problems.

This method shows elegance of mathematical solution techniques, but it has several limitations. While it will deliver a maximum (or minimum) by solving the system of differential equations, it does not provide any guarantee that this peak will not be a secondary one. For the successful application of this method the existence of the peak within the specified restrictions should be confirmed by other methods.

Method of steepest ascent

This method, widely used in ex-

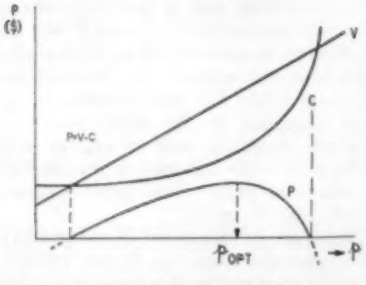

Figure 1. Variation of product V and operation cost C with operational parameter p.

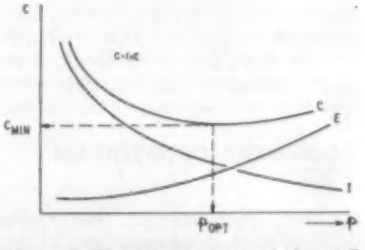

Figure 2. The cost components I and E change in magnitude in opposite directions thereby fixing the optimum at p_{opt}.

perimentation, can also be applied to design optimization. If we imagine the relations between the optimization parameters as represented by a multidimensional surface, with the profit as a dependent variable, the method will "seek out" the peak of the surface closest to the starting conditions by progressing incrementally in the direction of the maximum gradient. However, differentiation of the parameter functions involved must again be possible. There is also no guarantee that the peak found is not a secondary one. The method requires the use of a digital computer with good knowledge of mathematics and is presently not very popular. It is, however, the opinion of the writer that this method, possibly supplemented by suitable refinements, has still unexhausted potential for equipment design optimization. A particular advantage is its good adaptability to computer programming.

Case study method

The analytical methods described in the previous paragraphs had one property in common: they all required that it be possible to differentiate the functions relating the variable parameters. This condition cannot always be fulfilled. In many cases the optimization parameter will be a discontinuous or step function, or will have a form not suitable for differentiation. Under such conditions the analytical methods are not applicable, but use may be made of the "case study method". The mechanics of solution are the simplest possible: a set of complete design solutions for the equipment units involved are obtained at judiciously selected values of the optimization parameter scattered around the expected optimum point. If the first set of assumed values does not include the optimum, it will probably indicate the trend and subsequent selections will be progressively more accurate, until the optimum is reached or its position can be constructed as an inflection point of a curve.

The final presentation of the results is in a tabulation or, preferably, a graphical plot of cost vs. the operational parameter. To establish this relation, the solution of each case (i.e. the design to each assumed value of the optimization parameter) must be subjected to an individual economic analysis. This will consist, essentially, of establishing all the factors required for the solution of the operating cost equation; these are the initial equipment cost and the operating and maintenance cost. While the procurement of such values for each case will have the disadvantage of being inherently tedious, the accuracy of the calculation can be carried to any desired and individually controllable level. This is in particular contrast to the analytical methods, which permit only generalized cost definitions.

The result of these calculations will be a curve, in the case of completely continuous relations between the variables, or a step-function, in cases of dimensional or other restrictions. The evaluation of the results will include not only the primary objective of establishing the optimum design but the cost curve will show, in most effective form, information about the relations between the overall cost and the optimization parameter throughout a wide range of potential solutions. Moreover, because the design solution to each value of the operational parameter is subject to restrictions inherent to any particular situation, these solutions will be real and directly eligible for final selection.

A serious limitation of this method is that the result requires a graphical form of representation which is limited by the restrictions inherent in our three-dimensional space. Fortunately, many engineering design problems deal with not more than two simultaneous variables, and most of the others can be reduced to two by assuming selected values for the higher degree variables.

CRITIQUE OF METHODS

In summarizing the outstanding properties of the various optimization methods we can evaluate them with respect to their applicability to digital computer use. This criterion of quality is justified as the extent of calculation involved will almost invariably be beyond the capability of manually performed arithmetic.

Analytical methods

The analytical methods will undoubtedly deliver the most elegant solutions, but they will also have severe limitations:

1. The result of the analytical method will, in any case, be a single-point solution which will not give any indication about the curvature of the optimization surface around the maximum. Consequently, if the engineer has to deviate from the theoretical optimum because of construction limitation or other intangible reasons, this method will not give him any information concerning the direction in which such deviation should be made nor how much it will cost. If the shape of the optimum peak has to be explored, this will require the solution of a series of designs at selected values of the variables.
2. Many functions involving frequently encountered variables are discontinuous or step-functions, or for other reasons are not adaptable for differentiation. For example, the LMTD correction factor required for optimum solution of any heat exchanger problem is not differentiable. This limitation imposes severe restrictions on the validity of analytical methods for many heat exchanger optimizations.
3. The analytical method will require a special mathematical solution for each combination of variables and for each particular formulation of the problem. Deviations of the original engineering assumptions such as changes between laminar and turbulent flow and the mathematical representation of the transition region will often lead to prohibitive complications.
4. The conditions described above also imply that a special computer program would have to be com-

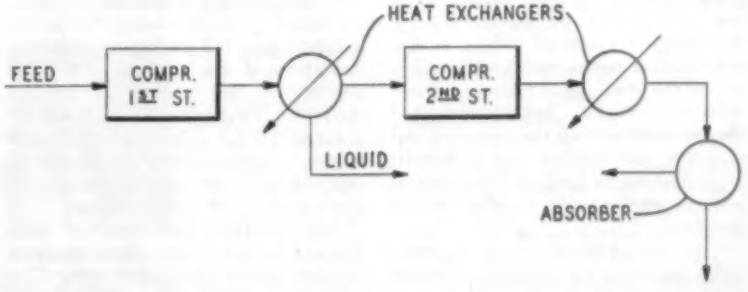

Figure 3. Stylized flow sheet of Cat cracker used in optimization example.

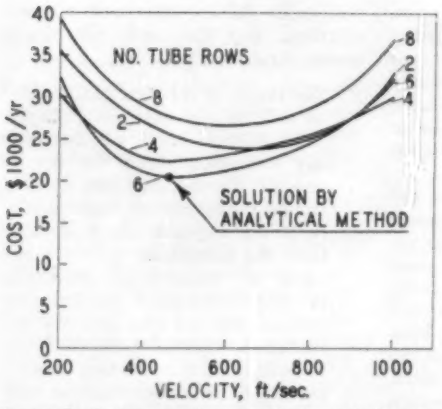

Figure 4. Optimum air cooler design solution as supplied by computer.

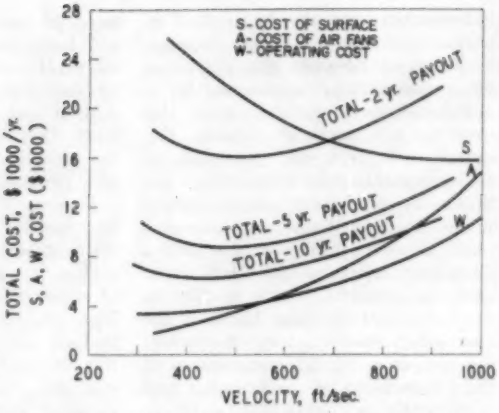

Figure 5. Cost analysis of air cooler: 4-tube row construction.

piled for each case. This would be true if we considered the optimization of the numerous possible combinations in groups of process units such as shown in Figure 4. Even if we assumed that the cost of programming would be economically justified, experience shows that the time lag between the problem conception and the availability of a debugged program would put the equipment designer to a severe test of patience.

The extent of calculations involved by the analytical methods is, contrary to superficial impressions, considerable for all but the simplest cases. This is true particularly if restrictions must be imposed on the parameters and the method of undetermined multipliers is used.

Case study method

The case study method is well suited for computer use. It has none of the limitations of the analytical methods.

Let us assume that a general program is available for designing certain process equipment. This same program can then be used for optimization calculations by simply solving the design for several values of the optimization parameter. Furthermore, any of the operational parameters and their combinations can be subjected to optimization with the same general program and without any additional programming as long as such parameters appear as input variables in the program.

The complete economic calculations, including an elaborate unit cost estimation, can also be included as a part of the computer program. The final evaluation of the results will usually be graphical. As a further refinement, subsequent guesses at the values of the optimization parameter can be internally generated in the computer, within limitations, as imposed by the problem data input. The author has compiled such an optimization program for Phillips Petroleum Company for the design of optimum air coolers with respect to air velocity and number of rows. The calculation requires about one minute on an IBM 709. An example is presented below.

A particular advantage of the case study method is that groups of various equipment units appearing in process circuits can be optimized by the method without developing a special program. Thus, compressor and intercooler optimization can be accomplished by the use of separate compressor and heat exchanger programs. An example of optimizing the combination of an air cooler and water cooler shell and tube heat exchanger by using two separate programs is also given below.

Currently, for the evaluation of multiple unit systems having a common parameter, separate programs, followed by a graphical interpretation, are being used. However, this is not a functional, but rather, a technical limitation of the method. As computers with larger memory storage capacities become available, it will be possible to have several equipment design programs working simultaneously, hooked up with only a simple, common logic of optimization.

The present limitation of this method to two independent variables is also not a functional one. The author can visualize a combination of the case study method with the method of the steepest ascent in which the generation of the subsequent guesses would be determined by a precise system; but the differentials would be replaced by final differences.

The building blocks of such a program would be independent equipment design programs. These could then be grouped in any desired combination, as dictated by the process, but their interrelation would be governed by a relatively simple over-all optimization logic, which would be the only part of the program special to any one case. The solution would be the construction of the actual contour of a multidimensional surface, the peak of which would represent the optimum solution. Such methods would be free of any restrictions except that of the calculation time involved. Presently, we can calculate the design of a shell and tube exchanger on the IBM 7090 in less than 10 seconds. With computer speeds increasing at their present rate, such systems will be possible in the near future and will probably represent the ideal solution for many optimization problems in the process industry.

Optimum design of air coolers

In designing an air cooler for a given temperature and duty, there are a large number of possible solutions with the air velocity v and the depth of the coils (number of rows n) being the variables. The higher the air velocity, the higher will be the air film coefficient and the smaller will be the unit required, but also, the higher will be the pressure drop and the work required of the fan. A higher number of rows will permit the concentration of large heat transfer areas

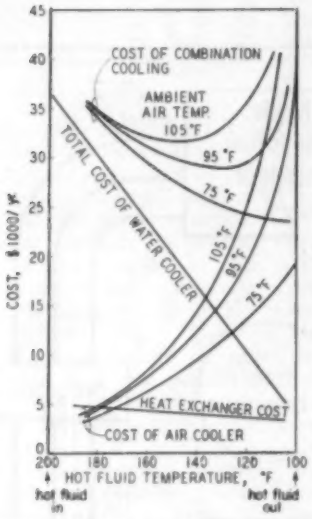

Figure 6. Economic analysis of air cooling vs. water cooling.

in small units, requiring less expense for structures. The film coefficient will (at least for induced draft) increase with number of rows as a result of better turbulency. The limitation is imposed, however, by high pressure drop, for which no suitable fan designs will be commercially available. The optimization of air cooler design by an analytical method has been shown by Kern (*5*).

Expressing the heat transfer area A, the pressure drop ΔP, and the air flow W with equations in terms of the operational variables v and n, we get, after differentiation, two simultaneous equations from which the optimum value of the parameters can be determined by a trial and error convergency. If the optimized design does not fit commercially available units, adjustments will have to be made, but the analytical method will not indicate the preferred direction of change or how much such deviation will cost. The simplified cost equation will also be valid only within a certain limited range of the parameters.

Optimization design by the case study method for this problem has been programmed for a digital computer. The basis of the program is a design solution of the air cooler for a given air velocity and number of tube rows. The engineer setting up the data will specify the lower and upper limits of v and n and the computer will automatically supply solutions of all possible combinations between these variables. The cost of each unit including air fans is estimated in the computer by solving a set of predetermined cost equations which can be made much more accurate than the generalized correlations used, by necessity, for the analytical method.

Solution of an example as supplied by the computer is shown in Figure 4, plotted as yearly cost vs. air velocity with number of rows in parameter. The curves do not show any consistent pattern due to the fact that non-practical solutions have been eliminated by the computer and adjusted to actually available units. The optimum falls into the 450-600 ft./sec. range, which coincides with the general predictions of the analytical method. One case (4-row design) is broken down in the cost components in Figure 5. The effect of payout time is also demonstrated, showing a shift to lower velocities with increasing payout time, i.e. toward designs with larger initial cost and smaller operating cost.

Optimized selection of air vs. water coolers

In this example, the problem is to cool a hot oil stream from 200 to 100°F. This can be done by air cooling, water cooling, or a combination of both. The economic decision in favor of any one of the possibilities will depend upon a number of process conditions: the temperature range of the hot fluid, inlet temperature and permissible rise of the cooling water, ambient temperature of the air, and some over-all economic factors; in particular the cost of supplying the cooling water.

For this example the cooling tower cost, including supporting facilities of $2,200/(B t.u.)(hr.), was assumed and 5% make-up water was required at a cost of $0.12/1000 gal. Payout time of 2 yr. with 10% interest rate on investment was set.

Complete design calculations for air coolers for three ambient air temperatures of 75°, 95°, and 105° were obtained from a computer program for various heat duties by holding the hot inlet temperature constant and assuming several values for the hot outlet up to the full cooling range. The economic analysis of each design was automatically supplied by the computer program and results plotted against the hot outlet temperature in Figure 6. The intercepts of these curves with the given hot outlet temperature shows the cost of the cooling by air alone. Note, that the 105°F ambient air temperature will intercept at an unrealistically high cost.

The cost of the water cooler was also determined from a computer program, but this time the hot outlet temperature (100°F) was kept constant while the heat duty was varied by changing the hot inlet temperature for the full range. The cost of the heat exchanger alone was raised only slightly despite the larger differences in the total heat duty, as these were offset by the increasing temperature differences. However, the amount of water with the corresponding charge for the cooling tower facilities was increasing steadily with the heat amount transferred. The intercept of the curve with the given hot inlet temperature determines the cost if water cooling is used alone.

For the 75°F air ambient temperature, total cooling by air is preferable by a wide margin. For 95°F the total air cooling would require slightly higher cost than total water cooling but the combination of air and water cooling with about 130°F trim temperature is the economic optimum. For 105°F ambient temperature total air cooling is impossible and the air-water combination with about 145°F trim temperature shows a distinct economic optimum.

Each of the air cooler designs taken as a basis for this evaluation was, by itself, an optimum design with respect to air velocity and tube row depth as supplied automatically by the computer program.

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ACKNOWLEDGMENT

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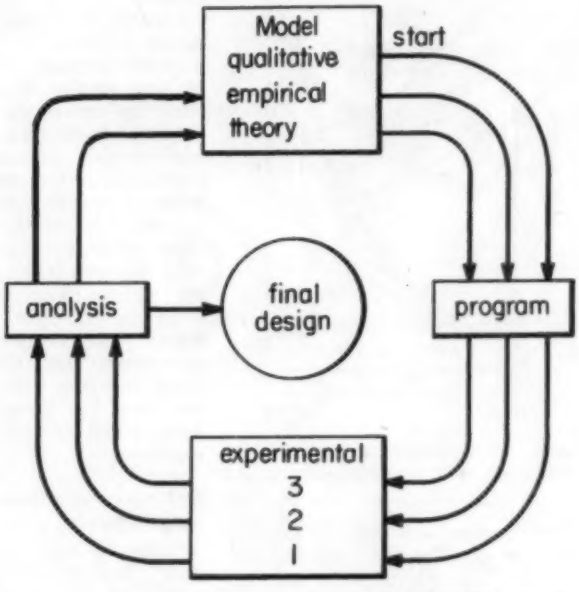
CLYDE BERG
Union Oil Company of California



Iterative process in experimental design.

Optimization in process development

Successful chemical processing depends on proper evaluation of broad alternatives and external variables and maximization of process and equipment performance.

OPTIMIZATION IS THE KEY to the successful culmination of any development venture, whether it is carried out by deliberate procedures or intuitively. With imperfect or inept optimization, even the most novel research effort can be nullified. Recently developed techniques of Operations Research and Systems Engineering represent attempts at conscious methods to carry out this function more successfully.

In this article, optimization is defined (*1*) as it is used in the field of Operations Research and briefly stated is "simultaneous consideration of all possible allocations of one's resources, consideration of the probable impacts of all exogeneous events, and the maximization, subject to certain initial constraints, of the utility function of the optimizer."

Optimization from the standpoint of conscious method application would be ideal if a broad conceptual and mathematical model could be immediately created for application to processes with subsequent arrival at procedures to guide development and final definition of the process. Unfortunately, it is rare that this can be accomplished. Nevertheless, decisions must be arrived at and considerations must be carried out in three major areas which, if not properly emphasized, may lead to less than optimum accomplishments. These are:

1. **Broad alternatives.** A factual review of critical aspects must be made to provide the basis to supplement Management's ideas and experience.

2. **External variables.** The effect of external variables on the stability and success of plant operations, particularly variables which are not controllable within the process boundaries, are important. The environment under which the process is expected to operate must be fully appreciated to make intelligent decisions and to set up proper criteria for process development.

3. **Maximization.** Equipment performance must be maximized within the constraints set up by the consideration of the first two steps and the criteria set up in the original research work and economic study of the project.

Process development alternates

Managerial experience and industrial position play a major part in choosing between alternates in the final scheme of a development. Generally process development is carried out by an organization which has accumulated years of experience in processing or manufacturing products not too far removed from the schemes of development under consideration. In the course of these operations, the company undoubtedly has developed a position in possession of properties, natural resources, and patents based on prior research efforts. Also, the company has an operations department staffed with

well-versed individuals having experience in the actual use of various techniques in commercial production, as well as an established market and a staff for potential exploitation of further products. A younger corporation may have few or none of the above assets and is rarely in a position to carry out large-scale process development. It is important that where these factors do exist, they play an important part in the considerations and the decision between broad alternatives of the development schemes.

Consider the case of mining and retorting of shale to produce shale oil as illustrated in Figure 1. There exists the broad alternatives of *in situ* retorting or combustion, avoiding mining and processing completely in both these cases. It is important that a review of technical, economic, and best-interest position of the corporation be reviewed before making a decision to proceed on perfecting mining and processing techniques per se. Perhaps some development effort should be expended on both schemes prior to the selection.

The decision as to whether a process should be carried out batch-wise or continuously certainly is in the area of broad alternatives. Any management decision in this area has a basic impact on subsequent development work.

Patent position. The patent position of a research organization continually develops. In some fields past research operations may very well have developed a patent position which dominates the field. Selection from the alternatives of process development can be directly affected by a corporation's position in this regard.

Operation experience. The operating departments, which must accept and use the new process, must be advised and sometimes will play an important part in process selection. For example, consider a catalytic process where regeneration is carried out versus an alternate which does not involve regeneration, but may have other stringent requirements to maintain this type of operation. The operating department may strongly recommend that developments should proceed along the line of non-regenerative operations because of prior experiences of problems in carrying out regeneration in large commercial units. On the other hand, the operating department may point out considerable problems in maintaining required quality control for non-regenerative type of techniques. Process development may favor the potential of carrying out an operation utilizing solid adsorbents as illustrated in Figure 2. However, the operating department may have had previous experience in the use of liquid adsorbents only and may recommend the use of this system in the development effort, thus recognizing and avoiding some problems in adaptation to a novel type of operation.

Marketing. Sometimes the scheme of development may involve broad alternates which directly effect the range of products to be marketed by the company operating such a process. For example, solvent extraction in upgrading naphtha leads to different products than a catalytic method. Marketing would dictate the process which yielded the product of greatest value.

Process evaluation and Operations Research go hand in hand in advising management in these broad alternatives.

External variables

The environment under which the process is expected to operate must be fully appreciated to make intelligent decisions as to the scope and nature of the process development required and to set up the proper criteria for success in the goal of development. The definition of the processing job to be done must be fully understood in order that the proper efforts are directed toward solving problems and meeting plant requirements.

All too commonly commercial plants are erected in the field and started up on a charge stock differing widely from the feedstock that

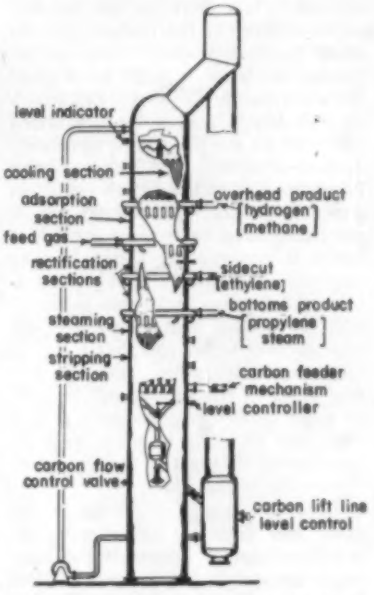


Figure 2. Use of solid adsorbents in a process is often based on past experiences.

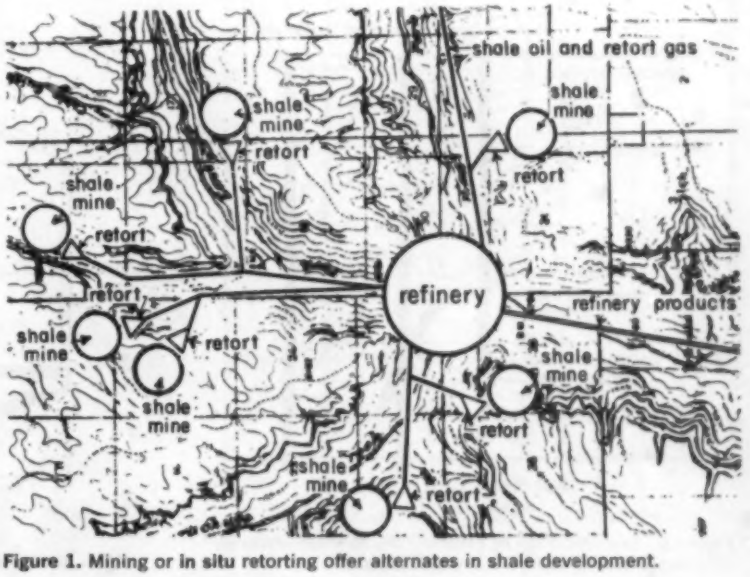


Figure 1. Mining or in situ retorting offer alternates in shale development.

was considered during a major portion of the process development. Certainly when a plant is able to handle such variations in the field modifications, it is a credit to the stability and versatility of the process. On the other hand, this often leads to degraded performance and loss of profits, which can be avoided if full analysis and recognition of the conditions under which the plant must ultimately operate is made. A full appreciation is required as to the future trends in product quality. Frequently plants are constructed to produce a product which is experiencing a year-by-year upgrading in quality and specifications. Protection must be made in light of market analysis so that the new process when completed and in commercial operation, possibly several years in the future, will be able to meet quality requirements at that time and continue to meet such requirements during the expected economic life of the plant.

Local operating conditions at the plant can distinctly affect the process development approach for optimum design. In certain areas skilled labor may be a distinct problem to obtain. Procurement of spare parts for maintenance of scientific equipment may be out of the question in remote areas. On the other hand, and even more probable, management may desire a fully automated plant to minimize labor force, as well as substantial investments in maintenance facilities to minimize turnaround expense.

The construction of a final commercial plant will involve substantial scale-up from pilot plant activities. Problems in scale-up though actually internal to the processing plant life may cause some repercussions of a completely external factor if not adequately anticipated. In Figure 3 there is an illustration of catalyst effectiveness developed in the course of a study of several catalytic processes showing the major effect of catalyst reactor shape when processing certain hydrocarbon stocks. Scale-up from pilot plant to commercial plant dimensions necessitates changes in reactor dimensions, and any changes in reactor efficiency must be anticipated. That this effect exists is illustrated in Figure 4 where the comparison in size and shape between a possible commercial reactor and a pilot plant reactor is shown.

Unexpected corrosion and erosion effects can strike almost with a disconcerting force in commercial plants where new areas of pressure, temperature, and concentration of corrosive materials are being processed in commercial equipment for the first time (*2*). The same is true of erosion factors where new materials may be moved in larger quantities than have been studied previously (*3*).

Maximization of performance

Maximization of the performance of process and equipment is the hard core of the problem of process development to which the bulk of the time and effort will be devoted. Although processes generally combine a considerable amount of routine design in the established areas, the critical and novel components generally require decisions in areas where little knowledge exists. In this key development area, data are generally quite limited. The procurement of specialized data to make decisions regarding process variables and equipment design is limited by cost and time, as well as personnel to develop this information. It is rare when a conceptual model can be created for the application of mathematical and scientific processes in arriving at procedures to guide development in maximization of the process. Suboptimization, concerned with the components of the process system, appears to offer the greatest potential for the scientific method. Hopefully, if a series of well-executed suboptimizations in the course of a process development are integrated, they will approximate optimization for the process involved (*4*).

Maximization of a new process generally is facilitated by considering the basic concepts of unit operations and dividing the over-all processing scheme to make maximum use of the prior scientific and engineering knowledge and principles available. Where a phase of the process has unique problems in scale-up or in process variables, optimization should be studied as fully as possible independent of the other operations to facilitate understanding of the unique characteristics.

Large-scale developments require major finances and major installation of facilities. The objectives of such development should justify such expenditures, and management should

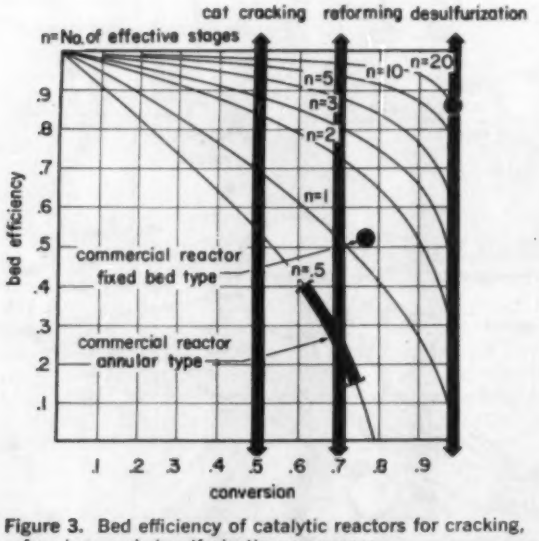


Figure 3. Bed efficiency of catalytic reactors for cracking, reforming, and desulfurization processes.

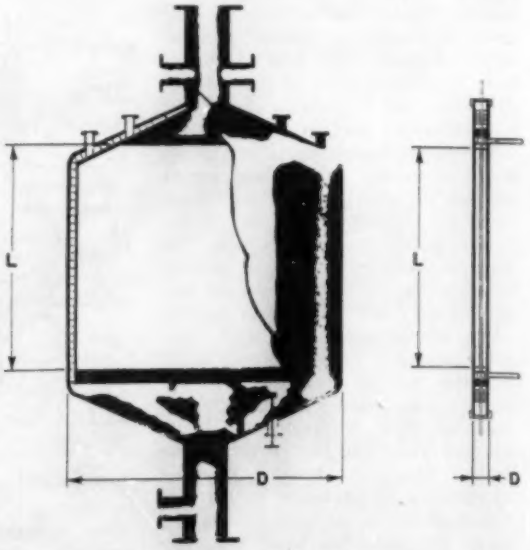


Figure 4. Scale-up of reactor from pilot plant.

Notation

C	= constant
c_v, c_L	= volumetric concentration
H	= column holdup, lb. moles of liquid
h	= column holdup, lb. moles of vapor
K	= constant
k	= mass-transfer coefficient
L	= rate of reflux flow in column, lb. moles/hr.
l	= length of lift line
n	= theoretical trays
p_j	= roots of Eq. 11a from Ref. 16
t	= time, hr.
V	= rate of boil-up in column, lb. moles/hr.
v_g	= gas velocity, ft./sec.
v_s	= solids terminal settling velocity
W	= solids loading, lb./sec./sq. ft.
X, X_w, X_o	= ratio of mole fraction of lower boiling component to mole fraction of higher boiling component in liquid; subscript w referring to bottoms, subscript o referring to composition of reflux
Y, Y_o	= ratio of mole fraction of lower boiling component to mole fraction of higher boiling component in vapor; subscript o referring to reflux
Z	= total length of column
z	= distance along column measured from condenser
α	= relative volatility

fully realize its responsibility in this regard.

The statistical design of experiments is rapidly growing in importance as a means of accelerating the acquisition of data in chemical reaction systems and has rapidly progressed since the classical work of R. A. Fisher (*5*). Recently, G. E. P. Box (*6,7,8*) has carried the application of statistics for chemical experimentation to a high level. Generally, modern statistical approach to experimental design recommends:

1. Construction of a model making use of mechanisms or relationships allowing for random phenomena.

2. A program for data collection aimed at maximizing definition of the model.

3. Analysis of the data for modification of the model, if necessary.

This approach is illustrated in the introductory photograph. The general technique of experimental scheduling is known as the iterative process and is not new to research work (*9*). With the recent incorporation of this concept in statistical handling, powerful tools previously unavailable are now available to the experimenter (*10,11*).

Development of the conceptual model, as well as the mathematical model, of key portions of the process and equipment should be the constant objective of process development in order to guide the experimental design, scientific development, and definition of the component. Use of reaction kinetics where the fundamental mechanisms are postulated and evaluated from apparent relationships of process variables can be of real value (12,13). If concrete models can be established early in development, spectacular economies and progress can be effected in defining optimum conditions.

Mathematical model

Consider the case of a catalytic treatment of petroleum naphtha where an extensive experimental program together with iteration and development of a mathematical model led to the general definition of reaction rate for this complex mixture. There were three important reactions which occurred in this case. The iteration process was carried out for each of the three reactions as follows:

1. Development of a semi-theoretical model for hydrogenation of olefins in naphtha after consideration of six conceptual models.

2. Development of a semi-theoretical model for dehydrogenation of naphthenes after consideration of twelve conceptual models.

3. Development of a model for desulfurization of petroleum naphthas of certain specified origin after consideration of seven different conceptual models.

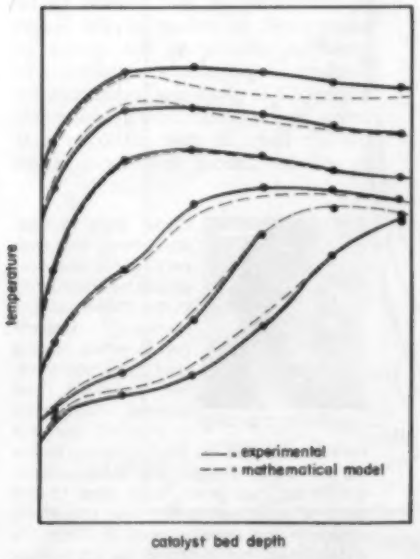


Figure 5. Temperature profile prediction.

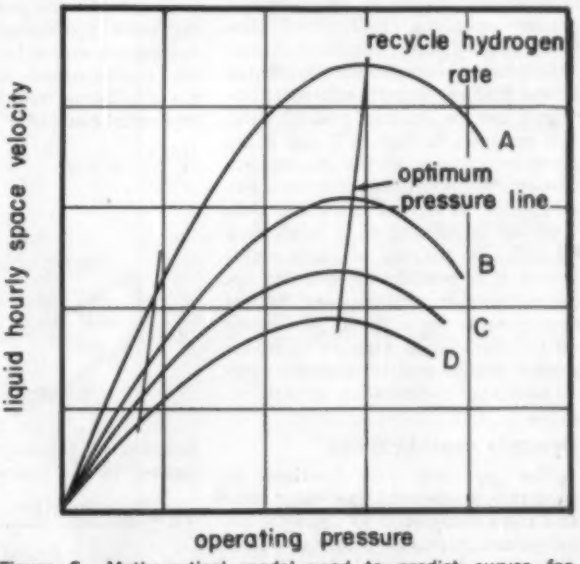


Figure 6. Mathematical model used to predict curves for optimum conversion of naphthenes to aromatics.

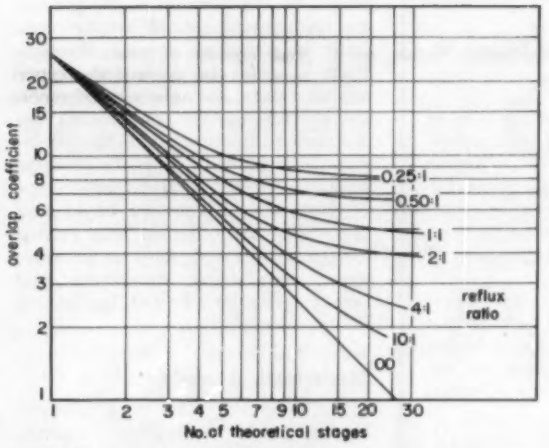


Figure 7. Overlap coefficient obtained from solvent extraction data in refining of lubricating oil.

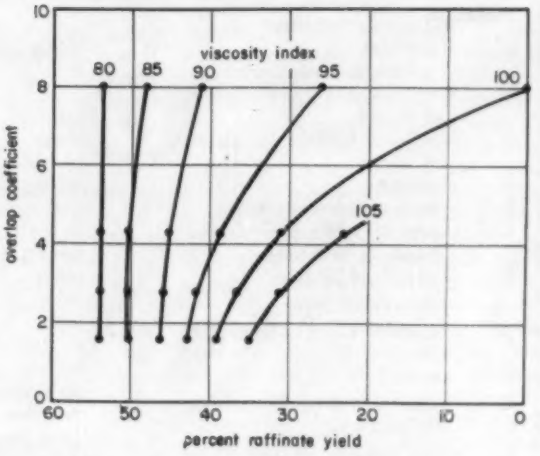


Figure 8. Data in solvent refining of lubricating oil.

The combined mathematical model was able to relate a wide range of data. As an example, Figure 5 gives a set of temperature profiles where stock was treated catalytically at a variety of temperature levels. In addition to correlating the results of product quality, the mathematical model predicted theoretically the pattern of temperature profiles illustrated by the dotted lines in the chart. The complexity of the reactions occurring in this pattern is such that success of iteration techniques and mathematical model development is a real credit to the mathematical power of these tools. This same mathematical model was able to predict a family of relationships for conversion of naphthene to aromatics, Figure 6, which would require extensive experimental runs to develop by purely empirical means.

Sometimes correlations developed in one field are directly related to optimum use in another related field. For example, in Figures 7 and 8 are given correlations of the overlap coefficient developed by Meyers (*14*) as applied to solvent extraction data obtained in refining of a lubricating oil (*15*). By the use of these correlations it is possible to optimize apparent number of stages and solvent requirements for a given lubricating oil refining unit as a guide to experimental design and to evaluate overall economic optimization as well.

Dynamic considerations

The dynamic considerations in process operations are becoming more and more recognized as areas for development in process systems. In addition to conventional instrumentation to maintain set pressures and temperatures, certain processes may well benefit by computer-type control of the more difficult operations. Possibly continuous control optimization by actual computer analysis of plant variations may be justified where such variations have a direct economic relationship to the profitability of the plant. Complete automation of a plant may be absolutely necessary where rapid and complicated types of procedures must be taken at key moments. Complete automation may be justified also on the basis of labor saving. Rate of approach to equilibrium may be of prime importance where large inventories are maintained in processing equipment in relationship to run lengths.

Faced with the problem of optimizing batch distillation column design, the experimenters in this case set up the mathematical model describing the distillation unit by the following two equations (*16*):

$$\frac{H\partial(X)}{Z\partial(t)} = -L\frac{\partial(X)}{\partial(z)} - kc_v c_L\left(\frac{1+X}{1+Y}\right)\left(X-\frac{Y}{\alpha}\right)$$

$$\frac{h\partial(Y)}{Z\partial(t)} = V\frac{\partial(Y)}{\partial(z)} + kc_v c_L\left(\frac{1+Y}{1+X}\right)\left(X-\frac{Y}{\alpha}\right)$$

Solution of this equation led to an answer in the following form:

$$Y_0 = X_0^n \ln \alpha(1 - z/Z) + \sum_j \frac{f(p_j)g(p_j z)}{(p_j+S)p_j g(p_j Z)} e^{p_j t - E_0(p_j)z}$$

This simplified to the following:

$$\frac{Y_0}{X_w} = \left(\frac{nL}{H}\right)(\alpha - 1)\,(\alpha \ln \alpha)$$

A good fit was obtained with actual experimental data as shown in Figure 9. The mathematical model was further developed into a form expressing total time for the plant distillation cycle and was maximized against investment and operating costs in the final analysis.

Equipment maximization

Equipment maximization is a key consideration in utilizing the fullest understanding of the process to be constructed, as well as specific design problems relating to the nature of mechanical operations involved. In Figure 10 is given the correlation relating to the design of a granular solids lift line. In this particular unit it will be noticed that the pressure

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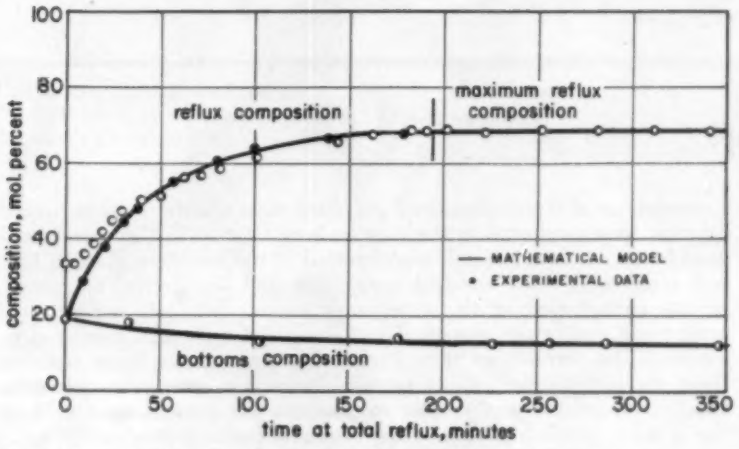

Figure 9. Predicting rate of approach to equilibrium in fractionation.

drop across the lift line increases as the gas velocity is decreased. Conversely, the pressure drop due to loss in the gas varies directly as the square of the gas velocity. The two factors combine to give an optimum and minimum total system pressure drop at an intermediate value in gas velocity.

The relationship presented in Figure 10 is a graphical representation of the following mathematical equation:

$$P_t = \frac{WL}{(v_g - v_t)\,144} + C + Kv_g^2$$

This simple model explains phenomena which would be quite confusing to experimenters attempting to develop the design on a purely empirical basis. If, for example, a centrifugal blower is used to supply gas circulation with typical automatic control of flow rate, the lift line will always stall at the point of reflection of the total pressure drop curve against flow rate because of the inability of the control system to cope with a rising characteristic of pressure drop with decreased flow rate.

Equipment maximization when closely associated with process performance, such as in contacting vessel design, process systems utilizing moving beds, (*17*), and high performance separation systems, frequently brings into play the need for the most advanced types of mathematical and technical analysis, together with actual mockup construction and operation for optimization in design.

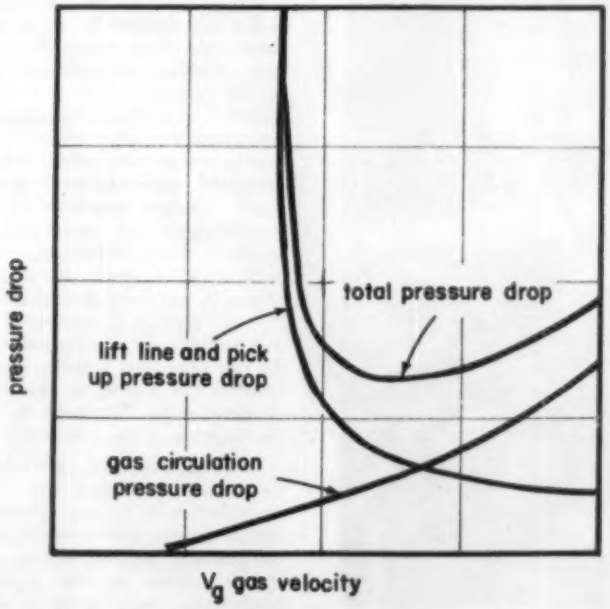

Figure 10. Correlation of pressure drop in dilute phase solids lift line.

Conclusion

Process development is fraught with problems in the application of scientific methods of design due to the natural penchant of individuals to make arbitrary decisions, as well as the economic pressure to make such decisions if the cost and time required for data procurement can be avoided. Decisions involving company position and the broad aspects of optimization should be as analytical as in the technical areas where conceptual models and mathematical techniques are used to the fullest advantage. The increased understanding of scientific methods of design, as well as the growing availability of both analog and digital computers, is contributing markedly to the utilization of these newer techniques in process development. Properly employed they can greatly facilitate the optimization of process and process components and avoid the costly expenditures which may be occasioned by unwise programs of development.

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Mass transfer efficiency —packed columns Part 2

Correlations of liquid phase and gas phase mass transfer rates in packed columns were presented in the July issue of CEP (3). The correlations were based on experimental data reported in the literature prior to 1957 and considered both absorption-stripping and distillation operations. In this second part of the series, new commercial-scale experimental mass transfer data are presented and compared with data predicted by means of the correlations from Part I. Comparisons are made between these correlations and others presently available for design purposes. Finally, procedures and sample calculations are presented as aids for the general problem of predicting required packing heights for given separations.

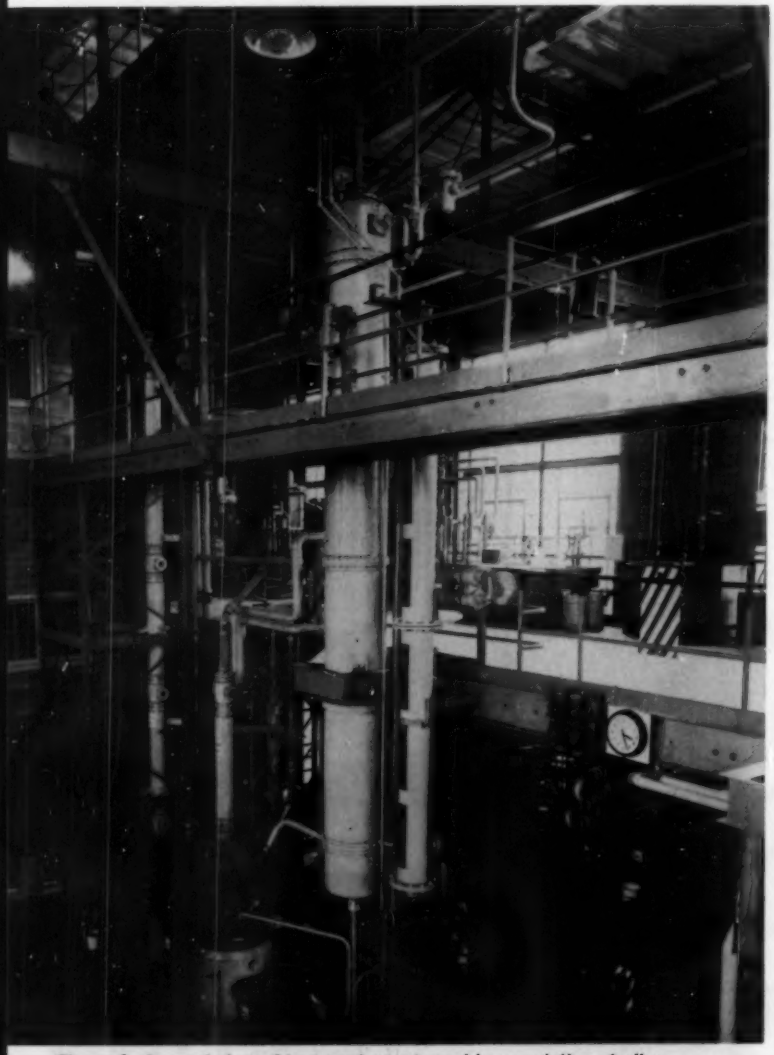

Figure 1. General view of test equipment used in correlation studies.

Commercial scale data

The experimental equipment used to test the commercial applicability of these correlations consisted of a reboiler, column, and condenser together with usual auxiliary facilities for studying continuous distillation in a packed column. Column diameters were 8, 16, 20, and 24 in. Packed heights ranged from 5 to 24 ft. In some cases intermediate vapor-liquid redistributors were used. A general view of the equipment is shown in Figure 1.

Several methods were used for directing reflux to the packing. Most of the experiments in the larger columns employed a multiport distributor, Figure 2, consisting of a number of vapor and liquid openings mounted in a metal plate and which distributes the reflux uniformly across the tower cross-section. Other experiments, particularly those in the small columns, employed a simple overflow-type unit providing a more localized initial contact of liquid and packing. This type of distributor, Figure 3, has been designated as the "crown" type, and consists of a cup with serrations spaced equally around the top edge, and a similarly serrated skirt on the bottom of the cup; the diameter of the distributor is one-half the diameter of the column.

The experimental procedure involved first charging the still pot (reboiler) with an appropriate quantity of binary test solution, of such composition that operation in the "pinch" zones of the vapor-liquid equilibrium curve could be avoided. The charge was then heated to boil-

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Monsanto Chemical Co.

ing with the column operating at total reflux. In the case of those packings requiring preflooding (McMahon), the column was operated under flooding conditions for a few minutes before adjusting the boilup rate. A run was continued at constant boilup rate and reflux ratio until analyses showed constant reflux and runback composition for at least one hour.

The principal system studied was benzene-ethylene dichloride at atmospheric pressure. Some runs were also made with the ethanol-water system at atmospheric pressure. Experimental physical property data were available from the literature, except for liquid and vapor diffusion coefficients, which were calculated (*5, 9*). Vapor-liquid equilibria for benzene-ethylene dichloride were based on the work of Bragg and Richards (*1*) and a relative volatility of 1.110 was used. For the ethanol-water system, vapor-liquid equilibria were readily available (*8*). Reference is made to the work of Delzenne (*4*) on the benzene-methylcyclohexane and toluene-methylcyclohexane systems. This work included experimentation in a 17.7-in. diam. by 6.6-ft. high column packed with 0.6 and 1.0-in. Raschig rings. Other work by Delzenne, involving less common packing types and smaller columns, is not of interest here.

Data handling

Transfer units for the measured separations were calculated from the Chilton-Colburn equation (*2*):

$$N_{OG} = \frac{1}{\alpha - 1} \ln \frac{X_T\,(1-X_B)}{X_B\,(1-X_T)} + \ln \frac{1-X_B}{1-X_T} \qquad (1)$$

Heights of overall gas phase transfer units were then calculated from the relationship

$$H_{OG} = \frac{N_{OG}}{Z_T} \qquad (2)$$

Predicted values of H_{OG} were calculated by means of the equation:

$$H_{OG} = H_G + m\frac{G}{L} - H_L \qquad (3)$$

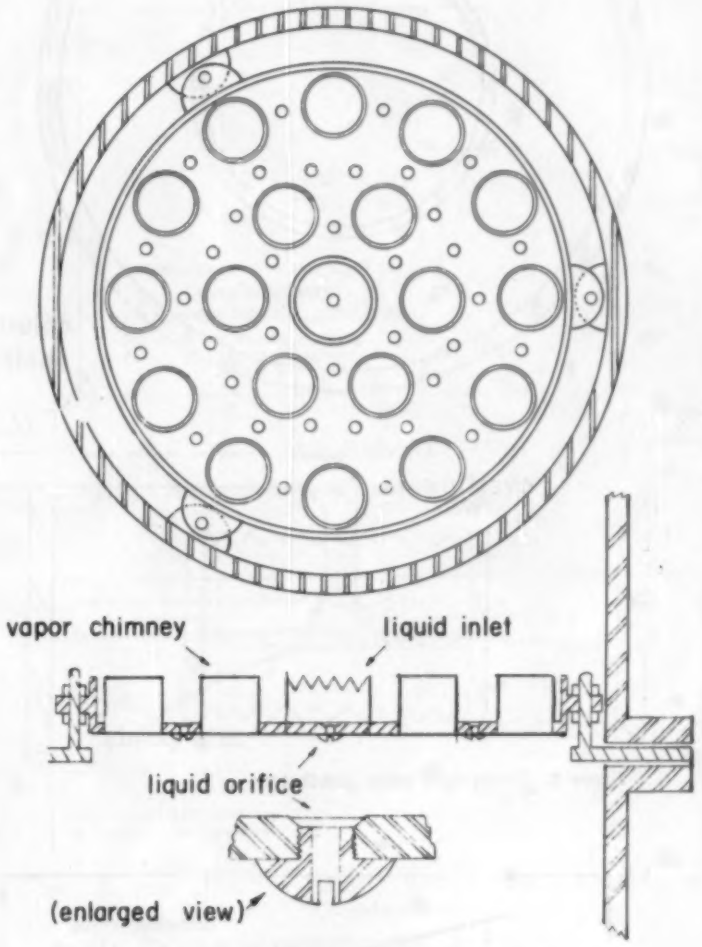

Figure 2. Multiport type reflux distributor.

where H_G and H_L were obtained from the correlations of Part I, and m from the relationship

$$m = \frac{\alpha}{[1 + (\alpha - 1)\bar{X}]^2} \qquad (4)$$

In the case of the Delzenne data, mass transfer efficiency was reported in terms of Height Equivalent to a Theoretical Plate (HETP). At total reflux and for the conditions studied, HETP values are approximately the same as H_{OG} values.

Results

Results of representative experimental runs are presented in Figures 4-9. In each figure the curve drawn was calculated on the basis of correlations given in Part I. All data were obtained at atmospheric pressure and total reflux.

In Figure 4 experimental and calculated values of H_{OG} are compared for the benzene-ethylene dichloride system and ½-in. Berl saddles. A crown type liquid distributor was used and there was no vapor-liquid re-

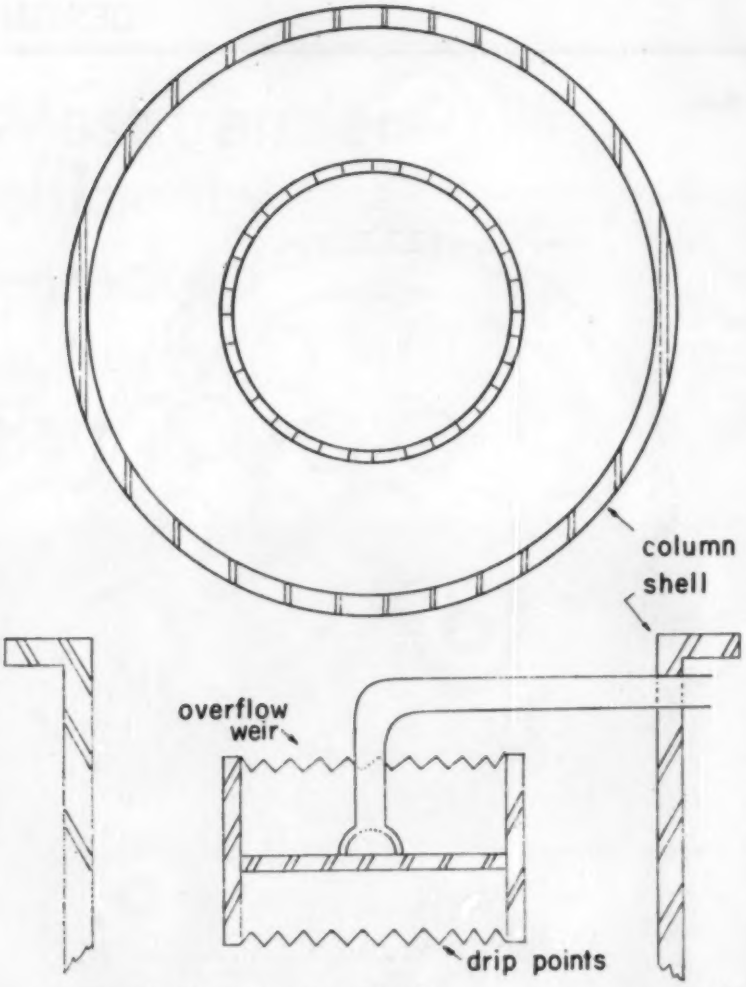

Figure 3. Crown type reflux distributor.

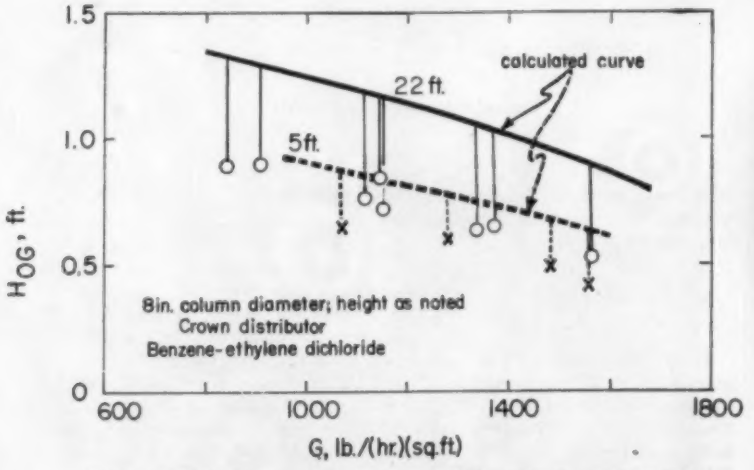

Figure 4. Height of over-all gas film transfer unit. H_{OG}, values for ½-in. Berl saddles.

distribution at intermediate points in the packing. For these conditions, the calculated values of H_{OG} are conservative.

Data for small McMahon packing are shown in Figure 5 and compared with data for Berl saddles. For both packing types a crown type liquid distribution method was used. It would appear that correlation parameters for Berl saddles apply to the same nominal size of McMahon packing.

Data for 1-in. Berl saddles and the benzene-ethylene dichloride system are presented in Figure 6. It should be noted that the column diameter is 24 in. As in Figure 4, the height correction appears somewhat conservative although a multipoint liquid distributor was used. The predicted curve agrees fairly well with the data for a crown type liquid distributor at the top, however.

Data for Intalox saddles are shown in Figure 7, with the calculated curve based on the equivalent Berl saddle correction parameters. Agreement between predicted and measured H_{OG} values is quite good at the higher throughputs. Intermediate distributors were used at 6-ft. intervals.

Two sets of data for the ethanol-water system are presented in Figure 8. For the larger column a modified multiport distributor was used at the top, and no intermediate redistribution was provided. For the smaller

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Knapp

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David Cornell is Associate Professor of Mechanical and Chemical Engineering, Oklahoma State U.

column, a crown type liquid distributor was used, and good contacting was not attained at gas mass velocities below 1000 lb./(hr.)(sq. ft.).

In Figure 9 data are presented for the benzene-ethylene dichloride system and ¾-1 in. Raschig rings. A single-port liquid distributor was used, and redistributors (with single ports for liquid) were located at 7-ft. intervals. At low loadings the relatively poor liquid distribution is apparent. At high loadings liquid distribution is good, and predicted H_{OG} values agree with those measured.

Data of Delzenne *(4)* are presented in Figures 10 and 11 for 0.6- and 1.0-in. Raschig rings. It should be noted that the systems were toluene-methylcyclohexane and benzene-methylcyclohexane. A multiport distributor was used. The experimental data were reported in HETP values, and insufficient information was given to enable conversion to transfer units. However, for the total reflux conditions HETP and H_{OG} should be nearly the same numerically. Again, it is seen that agreement between predicted and measured mass transfer rates is quite good, especially at higher loadings.

More work desirable

It has been shown that the empirical correlations of mass transfer in packed columns presented in Part I apply remarkably well for the test conditions used. The basic literature data, described in Part I, plus the data reported here, actually embrace a broad range of distillation and absorption conditions. Further validation of the correlations is desirable, particularly for distillations at reduced pressure. For the test conditions reported, the correlations of these articles are superior to the previously-reported correlations of Murch *(7)* and Granville *(6)*. Values of HETP computed by the Murch method gave average and maximum deviations of 300 and 400%, respectively, for ¾-in. Berl saddles. For 1-in. Berl saddles the corresponding deviations were 150 and 220%. HETP values computed by the method of Granville applied only to the "loading" condition and were in error by over 100% for the 1-in. packing sizes. The Murch and Granville correlations, as well as many others previously reported in the literature, suffer in that they do not separate liquid and vapor phase resistances.

For the rather diverse literature on mass transfer in packed columns that has been brought together and summarized here a correlation of the mass transfer data applicable to commercial-scale columns has been developed. This correlation is a semi-empirical combination of physical property and fluid mechanical variables; as in the case of mass transfer on bubble trays, this type of correlation has most chance of success in design work.

Design procedure

A stepwise procedure using these correlations for calculating the

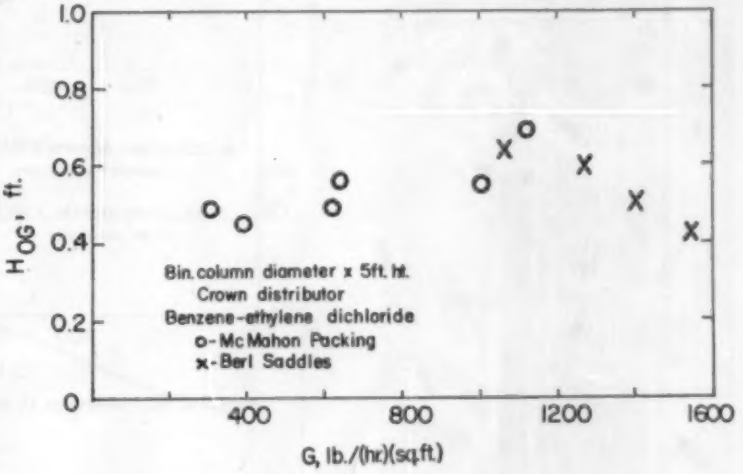


Figure 5. H_{OG} values for ½-in. packing.

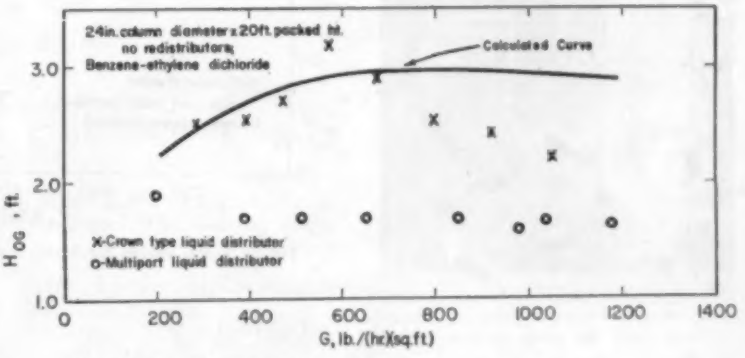


Figure 6. H_{OG} values for 1-in. Berl saddles.

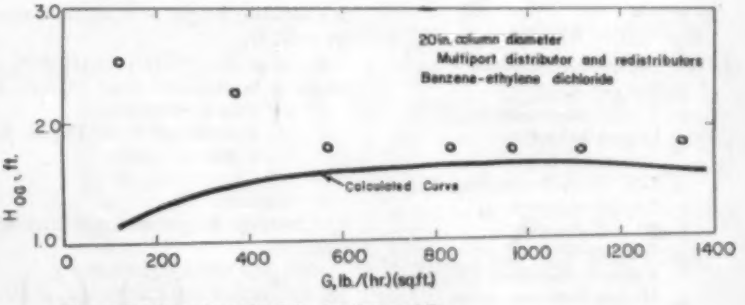
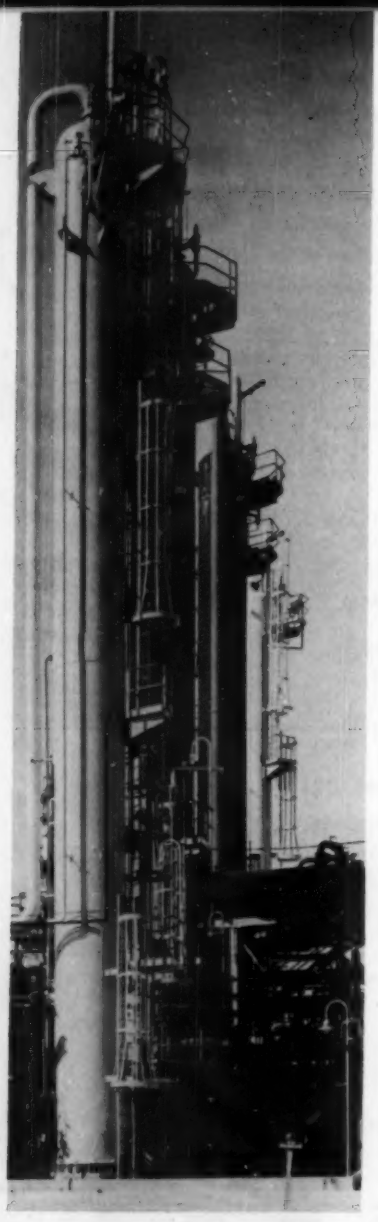


Figure 7. H_{OG} values for 1-in. Intalox saddles.



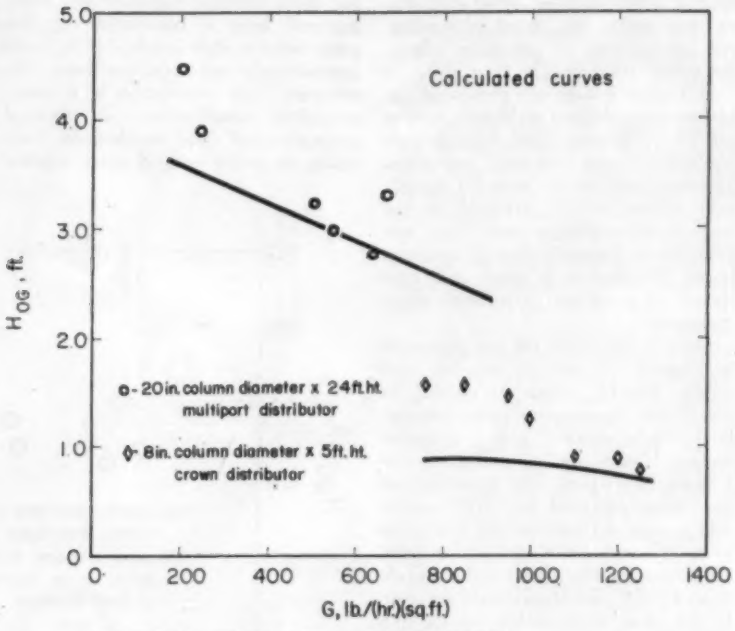

Calculated curves
o - 20 in. column diameter x 24 ft. ht. multiport distributor
◊ - 8 in. column diameter x 5 ft. ht. crown distributor
H_{OG}, ft.
G, lb./(hr.)(sq.ft.)

Figure 8. H_{OG} values for ½-in. Intalox saddles.

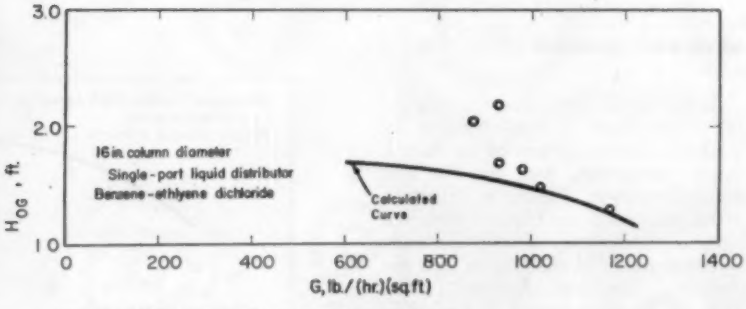


Figure 9. H_{OG} values for ¾-in. Raschig rings.

required packing height for a given separation is as follows:

1. Establish tower diameter for the given vapor and liquid flows, packing size and type, and desired approach to flooding.
2. List the design variables:
   a. Percent flood
   b. Liquid mass velocity, L
   c. Liquid Schmidt number, Sc_L
   d. Gas Schmidt number, Sc_G
   e. Liquid viscosity, μ_L
   f. Liquid density, ρ_L
   g. Surface tension, σ
   h. Column diameter, D
   i. Height between redistributors, Z
   j. Slope of equilibrium curve, m
   k. Molar ratio of gas to liquid, G_M/L_M
3. Calculate height of a liquid transfer unit, H_L:

$$H_L = \phi \cdot (Sc_L)^{1/2} \, (C) \, (Z/10)^{0.35}$$

where ϕ is obtained from Figures 4 or 5, Part I
C is obtained from Figure 2, Part I

4. Calculate height of a gas transfer unit, H_G:

$$H_G = \frac{\psi \, Sc_G^{1/2}}{(L f_1 f_2 f_3)^n} \left(\frac{D}{12}\right)^{1.24} \left(\frac{Z}{10}\right)^{1/3}$$

where ψ is obtained from Figures 9 or 10 Part I
$n = 0.6$ for Raschig rings, 0.5 for Berl saddles
$f_1 = (\mu_L/1.005)^{0.16}$,
$f_2 = (1/\rho_L)^{1.25}$,
$f_3 = (72.8/\sigma)^{0.8}$

5. Calculate height of an over-all transfer unit, H_{OG}:

$$H_{OG} = H_G + m \cdot G_M/L_M \cdot H_L$$

Sample calculation

The value of H_{OG} for the upper part of a benzene-toluene fractionator is to be calculated. On the basis of required throughput, the column I.D.

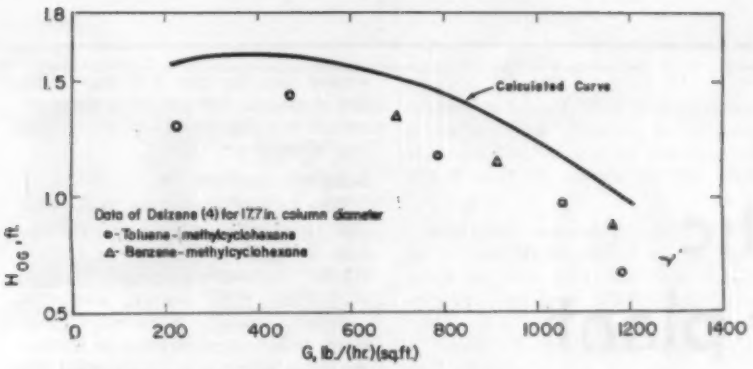


Figure 10. H_{OG} values for 0.6-in. Raschig rings.

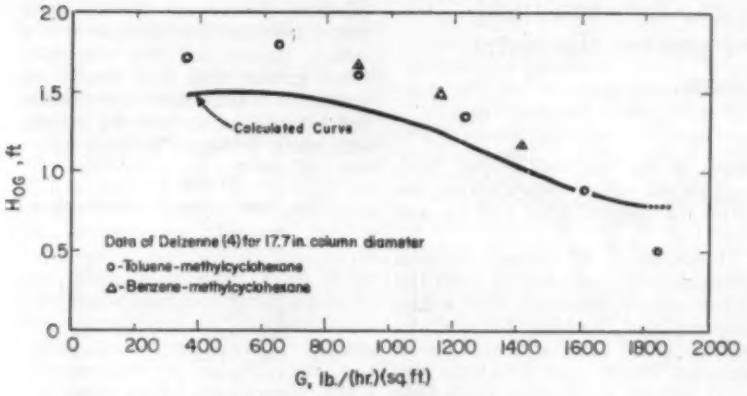


Figure 11. H_{OG} values for 1-in. Raschig rings.

has been determined as 30 in.; packing is 1-in. Raschig rings; approach to flooding is 55%; packed height between redistributors is to be 10 ft.
The design variables are:

a. 55% flood
b. L = 815 lb/(hr.) (sq. ft.)
c. Sc_L = 105
d. Sc_G = 0.81
e. μ_L = 0.32 centipoise
f. ρ_L = 0.694 g./cu. cm.
g. σ = 21 dyne/cm.
h. D = 30 in.
i. Z = 10 ft.
j. m = 0.40
k. G_M/L_M = 1.20

From Figure 4 of Part I, $\phi = 0.046$ for $L = 815$ and 1-in. Raschig rings. From Figure 2 of Part I, $C = 0.93$ for 55% flooding. Thus,

$$H_L = (0.046)\ (105^{0.5})\ (0.93)\ (10/10)^{0.15} = 0.44 \text{ ft.}$$

Factors f_1, f_2, and f_3 are calculated:

$$f_1 = (0.32/1.005)^{0.16} = 0.833$$
$$f_2 = (1/0.694)^{1.25} = 1.574$$
$$f_3 = (72.8/21)^{0.8} = 2.70$$

Then, $(L f_1 f_2 f_3)^{0.6}$
$= [(815)\ (0.833)\ (1.574)\ (2.70)]^{0.6}$
$= 119$

From Figure 5 of Part I, $\psi = 110$ for 55% flood and 1-in. Raschig rings. Then,

$$H_G = \frac{(110)\ (0.81^{0.5})}{119}\left(\frac{30}{12}\right)^{1.24}\left(\frac{10}{10}\right)^{1/3} = 2.60 \text{ ft.}$$

Finally,

$$H_{OG} = 2.60 + 0.40\ (1.20)\ (0.44) = 2.81 \text{ ft.}$$

NOTATION

C = correction factor for H_L at high gas rates
D = column diam., in.
f_1 = ratio of liquid viscosity at column conditions to viscosity of water at 20°C
f_2 = ratio of density of water at 20°C to that of liquid at column conditions
f_3 = ratio of surface tension of water at 20°C to that of liquid at column conditions
G = gas mass velocity, lb./(hr.) (sq. ft.)
G_M/L_M = molar ratio of gas to liquid
H_G = height of a gas-film transfer unit, ft.
H_L = height of a liquid-film transfer unit, ft.
H_{OG} = height of an over-all gas-film transfer unit, ft.
L = liquid mass velocity, lb./(hr.)(sq. ft.)
m = slope of vapor-liquid equilibrium curve
N_{OG} = number of over-all gas film transfer units
Sc_G = Schmidt number for gas phase, dimensionless
Sc_L = Schmidt number for liquid, dimensionless
$\overline{X}$ = average liquid mole fraction
X_B = mole fraction at bottom of column
X_T = mole fraction at top of column
Z = packed height between redistributors, ft.
Z_T = total packed height, ft.
α = relative volatility
μ_L = liquid viscosity, centipoise
ρ_L = liquid density, g/cu. cm.
σ = surface tension, dyne/cm.
ϕ = ordinate value in Figures 4 or 5, Part I
ψ = ordinate value from Figures 9 or 10, Part I

ACKNOWLEDGMENT

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R. E. LUND
St. Joseph Lead Co.

Electrolytic zinc pilot plant

This detailed description of an electrolytic zinc pilot plant fills the gap between fundamental electrolytic zinc process chemistry and commercial know-how.

FROM TIME TO TIME THE Research Department of Josephtown Smelter* has been called upon to do research for other divisions of the company. A most challenging recent assignment was to devise and develop a chemical method for winning values from a complex, refractory pyritic ore consisting of upwards of 65% pyrite. Gangue, composed principally of quartz, calcite, dolomite, and alumnia, comprised only 10-20% of the mineralized zones in the ore bodies. Zinc, lead, and copper values were variable, but averaged about 6.7% Zn, 2.6% Pb, and 0.4% Cu.

Investigation of several potential methods for the recovery of metal and sulfur values indicated that sulfate roasting and leaching followed by electrolysis of leach solutions showed promise. Bench and pilot-scale test work helped to establish procedures whereby over 90% of the zinc and copper in the ore could be solubilized by sulfate roasting and leaching. With a process for preparing feed stock worked out, the next step was to devise a scheme for purifying leach solutions to a degree that would permit zinc electrolysis.

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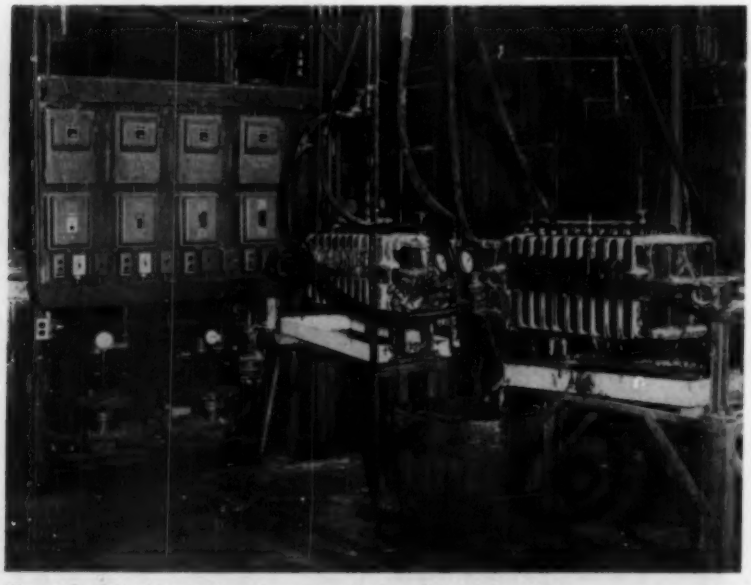

Figure 1. Filtering section for removal of purification residues.

Solution purification

The crux of successful electrolytic zinc production is solution purification. As recently discussed by Guy T. Wever (*1*), numerous impurities such as copper, iron, arsenic, antimony, cadmium, cobalt, germanium, selenium, tellurium, chlorine, and fluorine are either deleterious to successful zinc deposition or have a debasing effect which makes their removal mandatory prior to electrolysis. Analysis of leach solutions showed an unusual purification problem. The concentration of cobalt, arsenic, and iron was many times greater than that usually encountered in electrolytic zinc practice. Solubilization of some of the ore constituents is presented in Table 1.

Table 1.

Ore Composition, %		*Solubilization, %*
Zn	6.7	93
Pb	2.6	..
Cu	0.4	94
Fe	32.	2.4
S	38.	..
Co	0.03	74
Cd	0.022	88
Mn	0.18	68
Mg	1.47	95
As	0.2	10

Leach solution composition (with spent electrolyte recycle):

Zn–120 g./l., Cu–3.6 g./l.,
Fe–7.4 g./l., Co–214 mg./l.,
Cd–185 mg./l., As–200 mg./l.

Extensive bench-scale work in collaboration with Battelle Memorial Institute helped define the purification schedule: copper cementation; oxidation and precipitation of iron; cadmium removal; cobalt removal; and terminal purification treatment with zinc dust to remove the final traces of active impurities.

Copper removal. Removal of copper did not present a special problem because cementation procedures, employing scrap iron or zinc dust, removed most of the copper as a market-grade product. This treatment also removed a significant amount of the arsenic as an insoluble copper arsenide compound.

Iron and arsenic removal. Removal of iron presented a complex problem. Because of the significant concentration of ferrous iron in solution, usual chemical oxidants such as MnO_2 or $KMnO_4$ were undesirable since the quantity of manganese which would be introduced into solutions would

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exceed the tolerable level for good electrolytic zinc practice. Furthermore, oxidizing agents containing chlorine were impractical because the resulting chlorine concentration could not be tolerated.

For oxidizing iron a method was developed using air at near-atmospheric pressure. Of primary importance in achieving rapid oxidation is the introduction of air into the solution as fine bubbles. This can be accomplished by the use of porous grids or by mechanical agitators. Rate of oxidation is markedly sensitive to the pH of the solution. At a pH of 4.8 and above, oxidation is rapid and the iron precipitates as granular solids which have good filtering properties. Temperature above 70°C is necessary for rapid oxidation. Copper at 0.1 gm./l. or higher concentration appears to catalyze the reaction.

Oxidation and precipitation of iron was successful in clearing solutions of arsenic. The principal requirement for effective arsenic removal is that the minimum iron concentration be of the order of ten times that of arsenic in starting solutions. The iron oxidation procedure was effective in reducing concentration of iron to less than 10 mg./l. and of arsenic to less than 0.1 mg./l.

Cadmium removal. Removal of cadmium was accomplished by displacement reaction with zinc dust. Leach solutions contained 125-200 mg. Cd/l., which is a lower concentration than is usually encountered in electrolytic zinc practice.

Cobalt removal. The concentration of cobalt in leach solutions was of the order of 10-100 times that encountered in usual electrolytic zinc practice. Usual procedures for removing cobalt, including potassium antimony tartrate and copper sulfate-arsenious oxide-zinc dust treatment, were not sufficiently robust. However, alpha-nitroso-beta-naphthol was an effective precipitating agent for the cobalt.

To make the precipitant β-naphthol is dissolved in a solution of NaOH prior to its addition to the zinc electrolyte. $NaNO_2$ is then added and the electrolyte acidified to pH 3.0 with H_2SO_4. The $NaNO_2$ and β-naphthol react to form alpha-nitroso-beta-naphthol which, in turn, reacts with and precipitates the cobalt as cobalti-nitroso-beta-naphthol.

Electrolysis. Solutions purified according to the described schedule were satisfactorily electrolyzed in a 1400 ml. cell. Zinc of 99.9+% purity was produced. Current efficiency in excess of 90% could be achieved as long as the acid-zinc concentration in the electrolyte did not exceed a ratio of 3.5.

Pilot plant design

Bench-scale purification and electrolysis were promising enough to warrant study of an integrated process on pilot-plant scale. One objective of the pilot-plant study was to determine the extent of cyclic build-up of impurities in pregnant solutions when spent electrolyte from the zinc deposition cells was placed in closed circuit with the sulfating roaster. Pilot-plant design was based upon the following:

1. Cathode zinc production of 0.7 ton/day
2. Pregnant leach solutions of 125 g./l. Zn; spent electrolyte of 40 g./l. Zn
3. Pregnant solution flow rate of 1.5 gal./min.
4. Electrolysis current density of 33 amp./sq.ft.

Building. All of the purification-electrolytic circuit, except the copper launder, was housed in a 64 x 50-ft. galvanized steel, prefabricated building. The building floor, which was made of standard asphalt road material, had a modest grade, sloping to a common sump. This permitted recapturing spilled solutions, which assisted in making material balances.

Arsine. The high arsenic content of leach solutions presented a potentially serious arsine hazard. Arsine is an extremely toxic and insidious gas. To minimize the danger of arsine poisoning, the copper cementation

Figure 2. Zinc dust purification section.

Figure 3. Stripping cathode zinc in cell room.

launder was positively vented and was placed out of doors some 30 ft. from the pilot plant building. In addition, all purification tanks involving zinc dust addition were closed and remotely vented to atmosphere by a positive displacement fan. An automatic arsine detector was constructed and installed to monitor air continuously from various locations in the circuit.

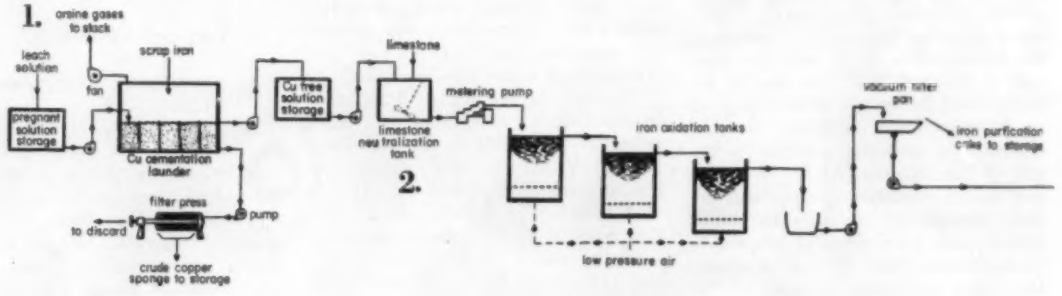
As an added precaution, a systematic check of urine analyses was inaugurated when the circuit was brought on stream. Although careful sampling failed to disclose presence of arsine, from time-to-time several of the operators showed considerably higher-than-average urinary arsenic. On two occasions, the situation was judged sufficiently critical that the pilot plant was shut down. When detailed examination of air analysis procedures and sampling locations by the Industrial Hygiene Foundation of America, Inc., showed that pilot plant exposure was not a significant source of arsenic, diets of the individual operators were investigated. A large amount of information, involving approximately 1000 urine determinations, was developed which showed that high urinary arsenics resulted from eating particular types of sea foods and fresh water fish. These findings have been reported (2).

Operating organization. The operation was run by four men per shift, including the shift supervisor. Supervisors were selected from second- and third-class operators in the Josephtown organization; remainder of the operating personnel were drawn from the labor pool. Training of the operators was done by members of the research staff working with the operating groups on a shift basis for a period of about ten weeks.

Purification control. A section of the pilot plant was equipped with laboratory facilities for making control analyses. Approximately fifty assays per eight-hour shift were made by the operators. The determinations included those for acid, iron, arsenic, copper, cobalt, and cadmium.

Investigation of cell performance

The pilot plant was operated on a three-shift, seven-day-week basis for



Flow Sheet

1 **Copper cementation.** Zinc-rich liquor from the leaching section pumped to the copper launder, a 17 x 11½ x 3-ft. rectangular wooden tank with capacity for about 7000 lb. of sheet iron trimmings; solution made to follow a tortuous path by inserting wooden partitions to form a labyrinth; temperature regulated to approximately 40°C using copper steam coils.

2 **Iron oxidation.** Copper-free solution pumped continuously to an agitated 3 x 3-ft. neutralization tank; pulverized limestone, fed from a cone-type reagent feeder, neutralizes any free acid in the solution in sufficient excess to meet requirements in the iron oxidation process; the slurry of liquor and limestone pumped to the first of a series of three oxidation units (each of the oxidation units a 3 x 10-ft. wooden tank); a plenum chamber covered with polyethylene cloth in the bottom of each tank disperses low-pressure air into the slurry as fine bubbles; temperature maintained with copper steam coils; reacted slurry overflows the top of each unit by gravity into the next unit; overflow from the final oxidation unit drops into a pump tank; slurry filtered batchwise on two horizontal pan filters.

3 **Cadmium cementation.** The cadmium cementation equipment includes two mechanically agitated 3 x 3-ft. wooden tanks arranged in series flow. Lead coils inside the tanks permit steam heating of the solution to operating temperature of approximately 60°C. Vibratory feeders, for zinc dust addition, are mounted above each tank; solution pumped continuously into the first tank and overflowed by gravity to the second tank; zinc dust fed continuously to both tanks; slurry discharging the second tank filtered for removal of cadmium sponge in a 12-in. plate and frame filter press.

4 **Cobalt removal.** Removal of cobalt from the zinc-rich liquor is carried out in three mechanically agitated 4 x 4-ft. wooden batch tanks. Temperature is maintained at approximately 60°C by lead steam coils. Normally, one of the tanks is being filled with liquor from cadmium purification while the operator adds reagents for precipitation to a second tank. Simultaneously, treated solution from a third tank is being clarified by pumping through a 12-in. plate and frame filter press. The cobalt-removing reagent is prepared by dissolving NaOH, $NaNO_2$, and β-naphthol in 60°C water. The reagent is transferred manually by hard rubber bucket to the cobalt treatment tanks where spent electrolyte is added to complete the reaction.

5 **Final purification.** Solutions are given a final purification treatment with zinc dust in a circuit identical to that used for cadimum removal. Purified solution flows to a check tank. Following checks for various impurities, solution enters the cell feed storage tanks.

6 **Cell room.** The cell room contains three commercial-size electrolytic cells arranged for series flow of both solution and of electric current. The cell tanks are made of reinforced concrete, lined with acid-

approximately six months. Although no lead-depressing reagents were used, the bulk of the zinc produced during the latter months of operation exceeded 99.99% Zn content. Cell feed solution had the following composition range:

Zinc	– 80 to 120 g./l.
Magnesium	– 10 to 26 g./l.
Iron	– 1 to 5 mg./l.
Copper	– 0.3 to 1 mg./l.
Manganese	– 1 to 2 g./l.
Cobalt	– 0.2 to 0.5 mg./l.
Cadmium	– 1 to 5 mg./l.
Arsenic	– less than 0.1 mg./l.

The effects of current density, of acid-zinc ratio, and of various impurities upon cell performance were evaluated using statistical methods. One of the significant findings was that magnesium at concentrations above 14 g./l. has a deleterious effect upon the porosity and associated brittleness of the cathode zinc. In fact, the need to limit magnesium to this concentration was one of the principal economic factors deterring commercial application of this process to the particular ore used as feedstock. The influence of acid-zinc concentration upon current efficiency was evaluated over a broad range. It was demonstrated that about 70% of the zinc could be electrolyzed from solution at current efficiency of 90%. Solutions could be stripped to a zinc content of 10 g./l. at a current efficiency of 40%.

Summary

The wooden tanks used as reaction vessels and for solution storage throughout most of the pilot plant proved satisfactory, in general. The only major leakage problem was associated with the copper launder, which was a rectangular tank. In several applications whiskey barrels were used to advantage; these proved to be ideally suited to a wide variety of uses.

Maintenance was excessive on the polyethylene grids used in the iron oxidation units. In any future operation mechanical agitators would probably replace the air grids.

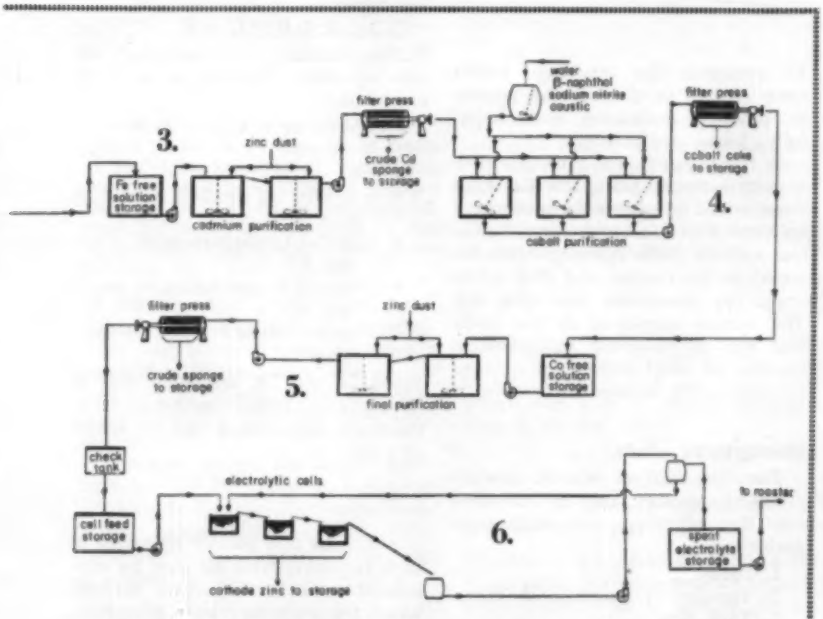
Several pumping problems were encountered. Gypsum build-up in hoses and pumps was, for the most part, confined to the limestone neutralization-iron oxidation circuit. Some types of centrifugal pumps proved unsatisfactory for pumping slurries at a uniform rate. Use of controlled-speed, air-actuated diaphragm pumps was effective in overcoming most of these problems. Centrifugal pumps (typically, 316 S.S.) rated 5 gal./min. at 10 lb./sq. in., proved highly satisfactory for pumping clarified solutions.

No particular problems were encountered in operation of the cadmium and cobalt purification sections. We are of the opinion, however, that improved purification would result if solutions were treated batchwise with zinc dust, rather than in a continuous system as employed in the pilot plant.

Cell room operation was smooth with the exception of periods when severe sticking of the zinc sheets to the cathodes was encountered. Conditioning of the electrodes by inserting them in spent electrolyte was effective in improving this condition.

Working with small quantities of solutions and of reagents poses problems in effecting close control in a continuously operating circuit. The approach we used in meeting this problem was to maintain frequent surveillance of flow rates, reagent additions, temperature, pH, and solution purity at each stage in the process.

Our experience indicates that a 0.7 ton/day electrolytic pilot plant can be operated to yield desired information. The pilot plant operation was successful in demonstrating process feasibility and in setting forth data which permitted economic appraisal of the proposed process.



resisting asphalt (reinforced with glass cloth) and one course of acid-proof brick bonded with a resin cement. Inside tank dimensions: 9 ft.-7 in. x 2 ft.-1 in. x 4 ft.

The 29 cathodes in each cell are made of modified 2S aluminum sheet, #6 B&S gage. Effective area of each cathode is 8.27 sq. ft., or 240 sq. ft. of cathode area per cell. Cathodes spacing on 3-in. centers maintained by spacer boards positioned in the tank shell; electrical contact with the aluminum header bars made with spring copper clips.

Each cell contains 30 anodes of 3/16-in. lead alloyed with 1% silver; anode sheets perforated with 9/16-in. square holes on 1-in. centers to promote solution circulation.

A copper oxide rectifier rated at 8000 amp. at 12 volts D.C. output with automatic current control was selected for the power supply to the cells.

Cell voltage drop varies from 2.8 to 4.0 volts per cell, depending on acid-zinc concentration in the electrolyte and current density. Cathodes are usually stripped on a 24-hour cycle. This involves removing each cathode from the cell, inserting a chisel point beneath one corner of the zinc sheet, and manually stripping the zinc from the cathode. Cathodes are "conditioned" to prevent sticking of the zinc sheets by soaking in spent electrolyte for a few minutes before returning to the cells.

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Tubular reactor at low flow rates

Increase efficiency of continuous tubular reactors by use of strategically-spaced baffles.

The design of chemical reactors is a matter of paramount importance to many chemical engineers, and much has been written about methods that may be employed for carrying out such designs (*2, 5, 7, 10, 15*). With the advent of precision automation, the trend in reactor design has been, where possible, toward the use of continuous reactors. The design of these reactors has been complicated by the inherent presence within them, in most cases, of a condition of axial mixing—or "backmixing"—which causes a decrease in the efficiency of the reactors.

It has been shown (*2, 7, 10*) that a flow reactor is most efficient; that is, it permits the greatest degree of conversion for a given reactor volume, when no backmixing is permitted to occur within it as the reactant stream passes through. This "zero backmixing" condition is approximated when the reactants flow through a tubular (longitudinal) reactor under conditions of turbulent (plug) flow. However, a disadvantage encountered in the use of tubular reactors at high flow rates arises from the fact that these high flow rates are apt to force the use of an extremely long reactor to assure that sufficient retention time is provided for in the reactor.

This article presents the results of a study of reaction kinetics in a tubular reactor at low flow rates which should be of interest as such rates allow a greater reaction time for a given reactor, or allow the design of a shorter reactor to perform a desired conversion. It might be expected, however, that these low (essentially laminar) rates would lead to considerable backmixing or its equivalent. To overcome this tendency, baffles were placed in the tubular reactor to produce turbulence and, hopefully, lessen backmixing.

In this investigation, a tubular flow reactor was operated at low Reynolds Numbers to determine the percentage conversion of reactants. Next, baffles —at various baffle spacings—were inserted in the reactor and their effect upon the conversion was observed. The system employed in the study was the second-order saponification reaction of ethyl acetate, in aqueous solution, with sodium hydroxide at 29.8°C.

Background study

For the sake of kinetic analysis chemical reactors may be classified into the following four main categories:

1. Batch
2. Tubular, or longitudinal, flow
3. Tank flow
4. Semi-batch (non-steady state)

Literature discussing the obtaining of kinetic data and their interpretation, as applied in the design of these reactor types, have appeared recently (*2, 4, 5, 9, 10*). Only a brief review will be presented here of the basic kinetic equations that have been developed for the first three reactor types listed. This survey will serve as background for the analysis of the kinetics of a second-order reaction taking place in a tubular reactor at low flow rates.

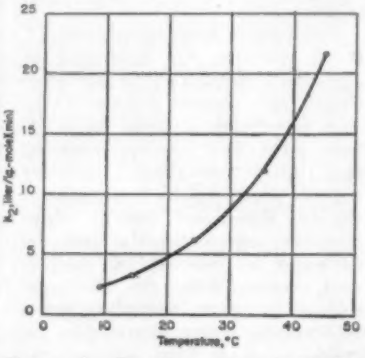

Figure 1. Reaction rate constants: NaOH + EtOAc → NaAc + EtOH

Consider a bimolecular reaction of the type:

$$A + B \rightarrow C + D \qquad (1)$$

If this reaction is second-order, the rate equation obtained in a batch reactor is:

$$\text{rate} = dx/dt = k_2(a - x)(b - x) \qquad (2)$$

where:

x = amount of product formed at time, t
a = initial concentration of reactant A
b = initial concentration of reactant B
k_2 = second-order reaction rate constant

When "a" and "b" are equal, that is, for equimolar initial concentrations of reactants, Equation 2 can be solved to yield:

$$(a - x) = \frac{x}{a k_2 t} \qquad (3)$$

A tubular flow reactor operating at high Reynolds Number may be considered as a batch reactor through which the reactants pass in plug flow; that is, with no axial mixing along the reactor. Thus the retention time t is directly related to the length, or volume, of tubular reactor through which a particular plug of reactants has flowed. For this longitudinal flow reactor, operated at high flow rates, Equation 3 becomes:

$$(a - x) = \frac{x}{a k_2 V/F} \qquad (4)$$

where: V = reactor volume
F = volumetric flow rate
V/F = retention time in the reactor, corresponding to t in Equation 3.

Another type of flow reactor, discussed by Corrigan and Young (*2*), Lessells (*7*), Sherwood (*9*), and Smith (*10*) is the "complete backmix" reactor (or stirred, tank-flow reactor).

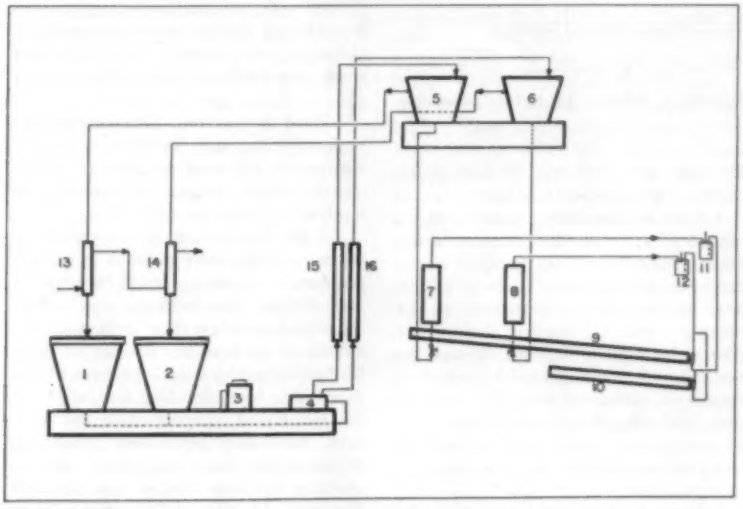

Figure 2. Schematic diagram of reactor test apparatus: 1. EtOAc storage tank, 2. NaOH storage tank, 3. Pump control variac, 4. Transfer pumps, 5. EtOAc constant head tank, 6. NaOH constant head tank, 7. EtOAc flowrator, 8. NaOH flowrator, 9. 6-ft. tubular reactor, 10. 3-ft. tubular reactor, 11. EtOAc bubble trap, 12. NaOH bubble trap, 13. EtOAc overflow cooler, 14. NaOH overflow cooler, 15. EtOAc auxiliary tape heater, 16. NaOH auxiliary tape heater.

In this type, feed is added and product removed continuously at equal mass rates. Once flow equilibrium is established in the system, the reactor operates at steady state and concentrations of materials in the reactor are constant.

Corrigan derives the design equation for the equimolar second-order reaction in the backmix reactor from a mass balance over the reactor. This equation, quite different in form from Equation 4, is:

$$(a - x) = [(F/2Vk_2)^2 + 2(F/2Vk_2)a]^{1/2} - (F/2Vk_2) \quad (5)$$

For any value of t or V/F, a value of x is obtained from Equation 5 that is always smaller than that obtained from Equation 4. Thus, a backmix reactor operated under the above conditions produces a lower conversion in a given reactor volume or in a given time than does a longitudinal flow reactor.

When dealing with reaction kinetics in laminar flow reactors, as in part of this investigation, the method developed by Denbigh (*3*) is useful. This development rests upon a statistical distribution of residence times in the reactor from a knowledge of the parabolic laminar flow profile. Basically, Equation 3 is combined with:

$$\bar{t} = 2t_0 \quad (6)$$

to give:

$$\bar{x} = 2a(ak_2t_0)[1 + (ak_2t_0)\ \ln\ (ak_2t_0)/(1 + ak_2t_0)] \quad (7)$$

where: $\bar{t} = V/F$ = average retention time in reactor

t_0 = time of passage down center of tube (minimum time)

$\bar{x}$ = average concentration of products at reactor outlet.

Equation 7 is a particular solution for the kinetics of a homogeneous second-order reaction in a tubular reactor operating with a parabolic flow profile and negligible diffusion.

Actually, molecular diffusion, either longitudinal or axial, should be considered. Bosworth (*1*) has studied this problem and has shown that in laminar flow diffusion may be neglected if:

d is greater than $36\sqrt{Dt_0}$ and
l is greater than $10d$
where:

d = reactor I.D.
l = reactor length
D = diffusivity of reactants.

These two conditions are satisfied in this investigation.

It was thought that the insertion of baffles in the tubular reactor might have either of two possible effects:

1. increase eddy turbulence and, thus, backmixing in the reactor
2. break up the laminar flow profile and thus increase the plug flow character of the flow.

It developed in this work that the latter effect was more important. The determination of the actual magnitude of the effect of placing baffles in the system was a primary objective of this investigation.

The reaction. The saponification reaction of ethyl acetate with sodium hydroxide in aqueous solution was chosen for this investigation for two reasons:

a. reaction rate constants for the reaction were well established, and
b. a simple, continuous analytical method (*13*) was available for the system. This reaction has been shown by many (*11-14*) to be bimolecular and second-order according to the following stoichiometric and rate equations:

$$\text{NaOH} + \text{EtOAc} \rightarrow \text{NaOAc} + \text{EtOH} \quad (8)$$

$$(a - x) = \frac{x}{ak_2t} \quad (3)$$

The stoichiometric equation, Equation 8, indicates an irreversible reaction. The investigators mentioned above have shown that in this reaction the equilibrium lies nearly to the point of complete reaction. Thus the reverse rate term is very small, and the assumption of essentially complete reaction, as written, is valid.

The solution of Equation 3 requires

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a knowledge of the value of the rate constant k_2 for this reaction. Therefore, values of k_2 were determined in a small batch reactor at several temperatures, and a plot of these values is shown in Figure 1.

The apparatus

A schematic diagram of the entire apparatus is shown in Figure 2. The constituent parts of the assembly are briefly described below.

Reactor. The flow reactor was constructed from a 6-ft. length of 1¼-in. I. D. polyethylene tubing. To prevent sagging, this tubing was supported along its entire length by Pyrex glass tubing, into which the plastic tubing was fitted. The tube assembly was clamped in place at a 5° angle with the horizontal. This slight upward slope, from the inlet to the outlet, allowed any air in the system to flow out of the reactor.

The 3-ft. long baffle assembly was mounted from the center of the 6-ft. length to the outlet end, from which end the baffles were inserted and removed.

Reactants were introduced into the reactor through a plastic "tee", which also served as a mixer for the reactants. Injection of the reactants into the reactor tube in this manner caused considerable turbulence in the vicinity of the reactor inlet. For this reason, 33¾-in. of calming section was provided between the reactor inlet and the baffles.

A second reactor, similar to the first but only half as long, was also constructed and mounted parallel to the first reactor and directly below it. This smaller reactor was used to determine the extent of the reaction in the first three feet (calming section) of the main reactor.

Auxiliary equipment. Reactants were charged to the system and stored in covered 30-qt. plastic tanks, Figure 2. From these tanks, reactants were pumped to the constant-head tanks located above the reactor.

These tanks, also of polyethylene and covered, had a capacity of 10-qt. ea. and were fitted with reactant outlets at the bottom, and overflow lines near the top which led back to the storage tanks. Inserted through the covers on the constant head tanks, and not shown in Figure 2, were the constant temperature control devices and the agitators. Knife heaters were used for heating the solutions in the constant head tanks, and temperature control was maintained by standard thermometer-relay systems. Flow control was provided by flowrators connected through needle valves to the outlets of the constant head tanks.

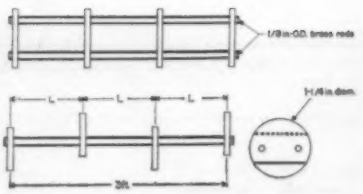

Figure 3. Sketch of baffle assembly.

Electrode assembly. Analysis of the extent of reaction in the system was accomplished by conductance measurement techniques. These conductance measurements required an assembly which would hold two electrodes rigidly in place. It was also necessary that the assembly provide a source of turbulent mixing in the region immediately ahead of the electrodes to insure uniformity of solution composition at the time of electrical measurement.

The electrode was constructed with a rubber stopper, large enough to fit into the 1¼-in. tubular reactor, as a base. Six holes were drilled in the stopper, and platinum electrodes were inserted through two of these. Another hole in the stopper held a 29 to 31°C range thermometer, and a fourth hole served as an effluent port for the reacting solution. The remaining two holes were used to support brass rods that extended several inches beyond the electrodes into the reactor. A brass ring was soldered to these rods at the ends extending into the reactor. This ring served to support a ¾-in. thick layer of glass wool which, in turn, provided turbulence and mixing in the reacting solution just prior to the conductivity measurement.

The electrical resistance of the solution was measured using a simple Wheatstone bridge circuit. Such circuits for measuring solutions are described by several references (*6, 8*). Electrical power was provided by a 1000 cycle oscillator, and a cathode ray oscilloscope was used as null indicator. Electrodes were platinized platinum.

Baffle assembly. A sketch of the baffle assembly is shown in Figure 3. The assembly was approximately 3-ft. long, and a total of 13 quarter-cut brass baffles, 1¼-in. diameter and ¾-in. thick, were made. The baffles were mounted on two 3-ft. long × ⅜-in. brass rods. Construction of the baffle unit for each baffle spacing required that the baffles be mounted on the rods a measured distance apart, lined up parallel with one another, and then soldered in place to provide a rigid structure.

The methods involved

For the saponification reaction, 0.1000 N ($\pm$0.0005) solutions of NaOH and EtOAc were prepared by standard techniques. The solutions were standardized once during each run.

Extent of reaction. The reaction between EtOAc and NaOH was chosen for use in this work because it offered a convenient, simple, and continuous method of analysis (*13*).

At the beginning of the reaction, when percent conversion is zero, the reactant solution consists of NaOH and EtOAc dissolved in water. The measured conductance indicates the extent of ionization. At the start of this process, the only ions present are those provided by the ionization of NaOH. Upon completion of the reaction, assuming equimolar quantities of reactants, ions are present in the solution because of the ionization of NaOAc. At any intermediate time, when a fraction x' of the OH^- ions have been replaced by acetate ions, the conductance is defined:

$$L' = L'_{Na^+} + x'L'_{OAc^-} + (1-x')\,L'_{OH^-} \qquad (9)$$

where:

L'_{Na^+}, L'_{OAc^-}, L'_{OH^-}, are electrical conductances in the solution due to the presence of these ions.

Solving Equation 9 for x':

$$x' = \frac{(L'_0 - L')}{(L'_0 - L'_f)} \qquad (10)$$

where: L'_0 is the conductance of the original solution: $L'_{Na^+} + L'_{OH^-}$

L'_f is the conductance of the final solution: $L'_{Na^+} + L'_{OAc^-}$

Thus, determination of x' depends upon conductance measurements at the beginning of reaction, at the completion of reaction, and at some desired intermediate time.

The technique has been used by Walker (*13*) to determine the reaction rate constant for the saponification of both methyl and ethyl acetate. Results agree with those obtained by other techniques (*11, 12, 14*). This procedure reduces the errors caused when samples must be removed from the reacting system and chemically or thermally treated to "freeze" the reaction.

Prior to the start of an experimental run, reactant solutions were prepared and placed in the feed storage tanks. The solutions were pumped continuously from the storage tanks to the

constant-head tanks, where the temperature controllers and heaters were in operation, and back again until the temperature of each solution levelled off at the control temperature, 30°C. This process took thirty minutes to one hour. At this time a sample of NaOH solution was analyzed and a sample of EtOAc was removed for later analysis.

At the start of the run, the electrode assembly with its glass wool turbulence section, was inserted into the outlet of the reactor, and the flowrators were adjusted to provide constant and equal volumetric flow of reactants. Equilibrium was considered to be attained when the conductivity of the reactor effluent remained constant for more than two minutes. The time required for the attainment of equilibrium normally varied from about 4 min. at the higher flow rates to 10 min. at the lower rates.

Recorder data for each run included the "known" resistance box reading, the slide wire position, flowrator readings, and the temperature. After these data had been recorded, the flow rates were adjusted to new values and, at equilibrium, the experimental data were once again recorded.

The end results

Backmixing has been defined (*5*) as the effect when "particles of feed intermix immediately with all other particles in a reactor, thus losing their identity". This is what happens in a tank-flow reactor in which the reactants are added continuously, products removed continuously, and the reactor contents are perfectly mixed.

It was mentioned earlier that the study of reactions occurring in continuous tubular reactors at low Reynolds Numbers is important because these flow rates permit the reactants to remain in a given reactor for a longer time than would be possible at the high rates required for plug flow. In addition, the use of low flow rates makes it possible to design shorter reactors than would be possible at higher flow rates (and correspondingly shorter retention times). These conclusions do not, however, take into consideration the differences in conversion per given reactor volume resulting from differences in flow pattern, and these effects may be considerable. It has been established that the greatest degree of reaction in a flow reactor occurs when the reactants are flowing at high velocities in true plug flow. Under conditions of laminar flow, a partial backmixing effect can be noticed at any cross-section in the reactor due to the differences in velocity of reactants at various positions within the cross-section.

The partial backmixing in such reactors at low Reynolds Numbers, due to the partially or fully developed laminar flow profile, may be quite serious. To overcome some of this effect, baffles may be inserted to break up the laminar profile and thus reduce the backmixing. The results of this investigation show the relative effects of the partially developed laminar profile and of the baffles—and various baffle spacings—on the conversion obtained in a continuous reactor.

Figure 4 shows the variation of conversion in a chemical reactor as a function of the reaction time. Three curves for the saponification reaction at 29.8°C are shown: the batch (identical to the longitudinal flow case), backmix, and partial backmix curves.

Curve *A*, is calculated for the batch reactor on the basis of Equation 3, is typical of any second-order homogeneous reaction with a one-to-one molar ratio of reactants.

Curve *C*, the backmix case, is also a calculated curve; based on Equation 5, another form of which is:

$$ak_2t = x'/(1-x')^2 \qquad (5a)$$

This curve represents a reaction process in which reactants and products are being added and removed from the reactor constantly, while holding the overall concentration of material in the reactor constant. Such backmixing decreases the rate of reaction and, therefore, the conversion per unit time by decreasing the concentration of reactants. This shows clearly in comparing curves *A* and *C*.

Curve *B* shows the conversion vs. time relationship in the open (unbaffled) tubular reactor operating at low Reynolds Numbers (440 to 1630, corresponding to flow rates of 560 to 2072 cu. cm./min.). This curve is experimentally determined and illustrates the basic point that the conversion in such a reactor follows neither the batch curve nor the complete backmix curve.

The experimental results for curve *B* can be compared to the predicted data of Denbigh (*3*). To do this, it is necessary to assume that flow in the experimental reactor has a fully developed laminar flow profile. The results of this comparison can be seen in Table 1, and it is apparent that the experimental and calculated (Denbigh's laminar flow model) conversions approximate each other.

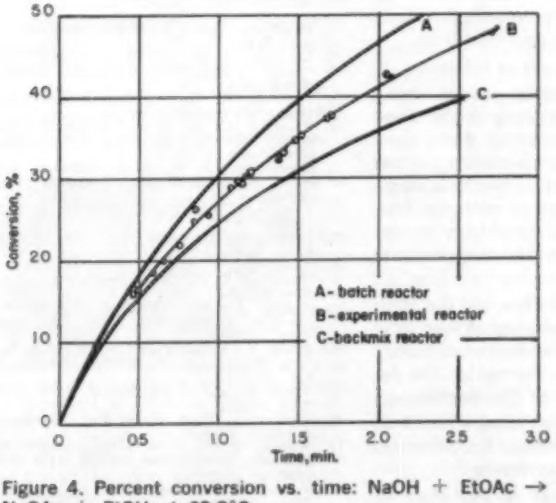

Figure 4. Percent conversion vs. time: NaOH + EtOAc → NaOAc + EtOH at 29.8°C.

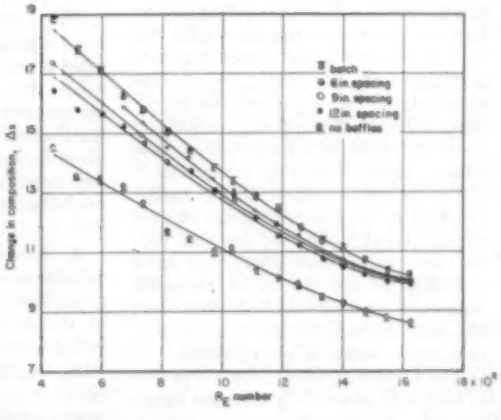

Figure 5. Change in composition Δx vs. Reynolds Number.

Table 1. Comparison between Denbigh prediction and experimental data, 29.8°C

TIME, MIN.	CONVERSION CURVE B FIGURE 4	DENBIGH
0.0	0.0000	0.0000
0.5	0.1675	0.1710
1.0	0.2710	0.2740
1.5	0.3510	0.3522
2.0	0.4120	0.4145
2.5	0.4620	0.4666
2.75	0.4835	0.4920

The point in this investigation, however, was not to prove Denbigh either correct or incorrect in his analysis but, rather, to show whether or not conversion in this type reactor followed a different relationship than do the batch or backmix cases.

Figure 5 illustrates the effect of baffles on a system operating on the partial backmix (laminar flow) curve. These curves show the change in composition, Δx, across the 37½-in. reactor section as a function of the flow rate for the following cases:

1. Batch (longitudinal flow) reactor—calculated
2. 6-in. baffle spacing
3. 9-in. baffle spacing
4. 12-in. baffle spacing
5. Open tube—no baffles

In each case the reactant stream entering the reactor section of the experimental tube possessed a well developed laminar flow profile. Upon striking the baffles, this profile was destroyed, with beneficial results. It is interesting to note the large difference between the curve for no baffles and that for the widest baffle spacing used. This difference points out that even an occasional baffle provides much more efficient reaction conditions than no baffle at all. It is also interesting to note that as the flow rate increases, the curves for the baffled reactors come closer together and approach the batch curve. This indicates that, as expected, the conditions in the baffled reactor approach those expected in a longitudinal flow reactor as the flow rate increases.

The beneficial effect of the baffles may really be a combination of two effects: break up of the laminar profile and subsequent formation of a turbulent profile typical of Reynolds Numbers greater than 10,000; or, effective division of the tubular section into a series of stirred tanks.

The formation of a turbulent profile of flow will allow the use of the longitudinal equations for reactor design. This can be accomplished either by using high flow rates or by using enough baffles in the reactor to assure approximately plug-type flow conditions, as illustrated in Figure 5.

Young (*15*) has shown that for a series of more than five continuously stirred reactors, the over-all effect is for the series to approach operation as a longitudinal reactor. In this investigation, the baffles divided the complete reactor into 3-, 4-, and 6-sections for the 12-, 9-, and 6-in. spacings respectively. These units were not, however, perfectly stirred and Young's methods of handling the system did not apply exactly. Nevertheless, the pattern described by Young was followed since, as the number of sections increased, the over-all conversion approached the longitudinal reactor limit.

This work has shown that the conversion in a continuous reactor is not a simple process capable of being expressed by the equations for the batch or backmix cases. The use of baffles may be one technique that can be employed for increasing the conversion in a continuous tubular reactor at low flow rates.

Conclusion

The objectives of this work were to determine whether either theoretical batch or backmix equations applied to reactions occurring in an open tubular reactor at low flow rates; and to determine the effect upon the reaction of placing baffles, at various baffle spacings, in the reactor. The conclusions reached apply specifically to second-order homogeneous reactions with a molar ratio of reactants equal to one and with initial reactant concentrations of 0.0500*N*. However, it seems reasonable to suspect that these same tendencies, at least, would be observed in reacting systems not completely fulfilling these conditions.

The conclusions are as follows:

1. Reaction kinetics in an open tubular reactor operating at low Reynolds Numbers (laminar flow) may not be predicted accurately from either the theoretical batch or backmix equations. In the absence of contrary data, the application of Denbigh's model might be the best available approximation.

2. Insertion of baffles into the open tubular reactor, operating at low Reynolds Numbers, increases the efficiency of the reactor, as shown by the increased conversion in the reactor.

3. Baffle spacings of as wide as 12 in. ($l/d = 9.6$) provide a marked increase in reactor conversion.

4. Baffle spacings of less than 12 in. are progressively better, as the spacing decreases, in increasing conversion in the reactor. However, the decreased baffle separation and the additional numbers of baffles required does not offer as much improvement over the 12-in. spacing as the latter does over the open reactor. This is especially true as the flow rate increases.

5. The trend in conversion as a function of baffle spacing indicates that as the spacing is decreased, the conversion approaches as a limit that which would be obtained in a longitudinal reactor.

NOTATION

a	=	initial conc. of reactant *A*
b	=	initial conc. of reactant *B*
d	=	reactor I.D.
D	=	reactant diffusivity
F	=	volumetric flow rate
k_2	=	second-order reaction rate constant
l	=	reactor length
L'	=	electrical conductance
t	=	time
$\bar{t}$	=	average retention time in laminar flow reactor
t_0	=	minimum retention time in laminar flow reactor (time of passage of materials through center of reactor)
V	=	reactor volume
V/F	=	retention time in flow reactor; corresponds to t
x	=	amount of product (same units as a and b)
$\bar{x}$	=	average concentration of products at laminar flow reactor outlet
x'	=	fraction converted
dx/dt	=	reaction rate

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Zygographic solution of vapor-liquid equilibrium

An unusual graphical representation called a zygograph makes use of projective geometry to solve binary distillation problems.

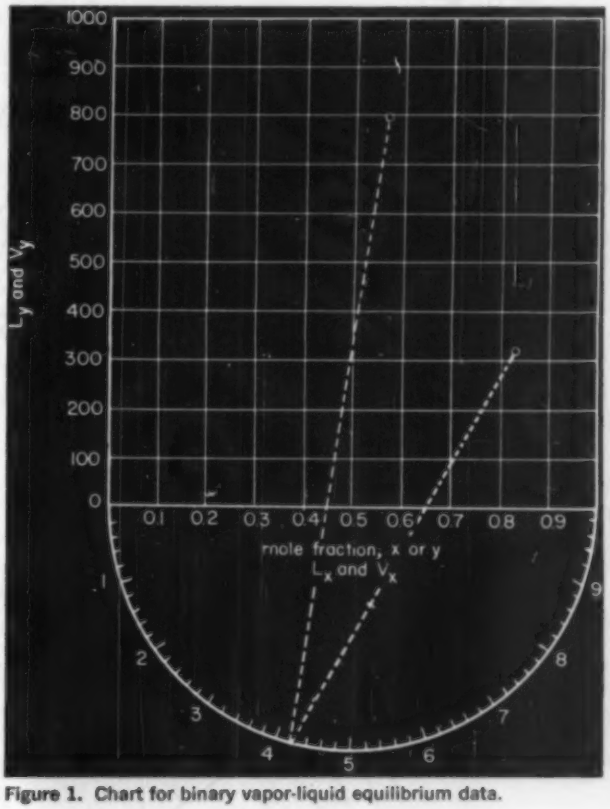

Figure 1. Chart for binary vapor-liquid equilibrium data.

AN UNUSUAL GRAPHICAL METHOD for solving binary distillation problems has been proposed and developed by Bloomfield (*1, 2*) which utilizes the "zygograph", a name coined by him. It is an interesting application to chemical engineering of projective geometry, a branch of mathematics which has a few such applications. As a general method of calculation it does not appear to have any advantages over existing simpler methods, but there is at least one worthwhile and unique application: a large amount of binary vapor-liquid equilibrium data can be represented with good accuracy on a single easy-to-use chart.

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As shown by Figure 1, the chart consists of horizontal diametral axis, a semicircle, and a grid. For greater accuracy than is possible here, a superior chart can be constructed on a sheet of ordinary graph paper. The axis is graduated in mole fractions of either x or y; the semicircle is graduated only for convenience. Two vertices, whose Cartesian coordinates are given in Table 1*, may be located on the grid for each system. Rays to the vertices from any particular point on the semicircle intersect the diametral axis in corresponding values of liquid and vapor compositions. For instance, the construction of Figure 1 shows that for the acetone-ethanol system, $x = 0.45$ when $y = 0.645$. Accuracy is generally well within half a division when an axis 10-in. long, marked off into 100 divisions, is used.

** Table 1 presents only a portion of 180 sets of equilibrium data, including most of those in the compilation of Kirschbaum (3). The complete table, containing many other systems such as acetic acid, benzene, ethane, heptane, and water are available from ADI as ADI No. 6332*

Locating vertices

Vertices are located by successive approximation. About half of those in the table were located by a "three-point" method which used three sets of representative $x - y$ data, and the others by a "four-point" method. The x and y are located on the diametral axis and the construction proceeds as follows, shown in Figure 2:

1. Arbitrarily, select point A on the semicircle.
2. Construct lines through Ax_a and Ay_a. The vertices lie along these lines.

continued on page 65

Figure 2. (right) Three-point construction for methanol-water system.

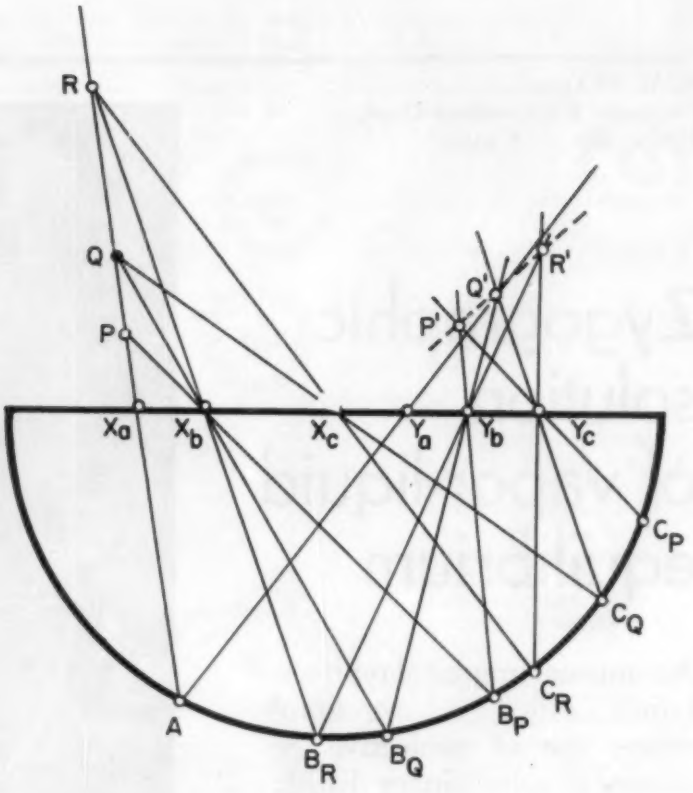
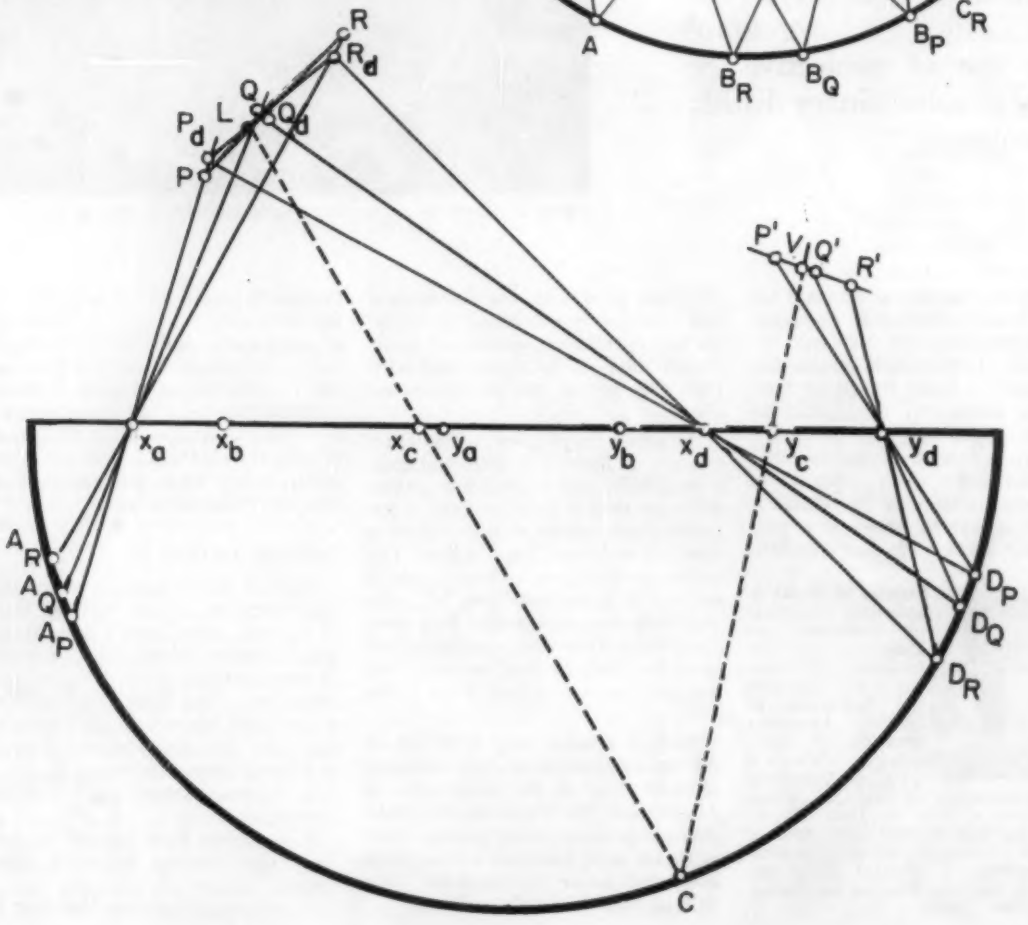


Figure 3. (below) Four-point construction for methanol-water system.



3. Choose a point R on line Ax_a and construct lines Rx_b and Rx_c, which in turn locate points B_R and C_R on the semicircle.

4. The lines $B_R y_b$ and $C_R y_c$ intersect at point R'. If R' had fallen on line Ay_a it would have been the vapor vertex.

5. If R' is not the vertex, try other points Q, P, etc. on line Ax_a and locate the corresponding points Q', P', etc.

6. The intersection of the locus $R'Q'P'$ with Ay_a is the vapor vertex, which is Q' on Figure 2.

Clearly, the location of point A determines the positions of the vertices and may have some effect on the accuracy of the representation. Also, the choice of data points affects the accuracy. In most of the results shown here, several possibilities had been checked.

A set of vertices can be fitted to four sets of x–y data. This is the most accurate representation possible by this method, and corresponds to the fitting of a fifth degree algebraic equation to the data. The four-point representation is unique, that is, there is only one set of vertices (L, V) satisfying four equilibrium points. The procedure is as follows:

Using only three of the points, several three-point vertices are located by the procedure explained above, corresponding to positions A_P, A_Q, and A_R on Figure 3, for example. The loci of these vertices are curves PQR and $P'Q'R'$ on this figure. The fourth set of data (x_d, y_d) must now be fitted. Accordingly, these constructions are made in sequence: Line $P'y_d$ locates D_p on the semicircle. Line $D_p x_d$ intersects $A_p x_a$ at P_d. Similarly Q_d is located on line $A_Q x_a$, and so on. The locus $P_d Q_d R_d$ intersects the locus PQR at point L which is the correct liquid vertex. Finally, line Lx_c locates point C and line Cy_c intersects locus $P'Q'R'$ at V which is the correct vapor vertex.

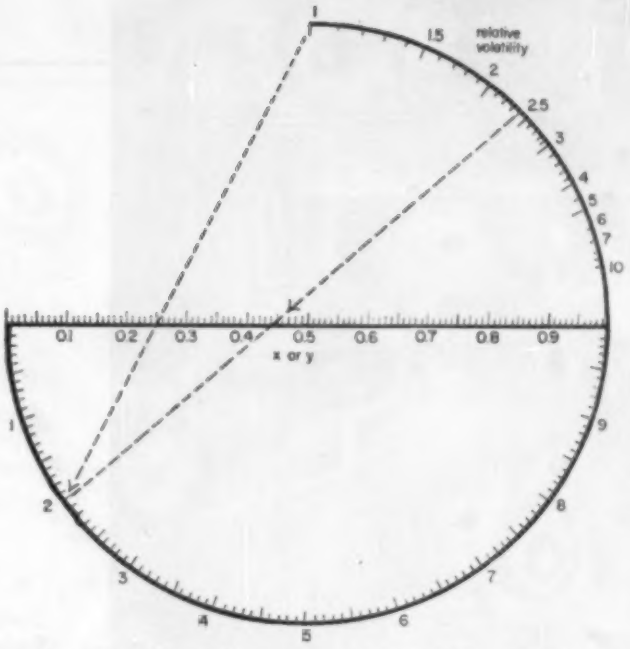


Figure 4. Vapor-liquid equilibrium with constant relative volatility.

Mixtures having constant relative volatility, with equation

$$y = ax/(1 - x + ax),$$

where a is the relative volatility, are especially simply represented. On Figure 4 the liquid vertex is fixed at 1 on the a-scale and the vapor vertex is at the value of a for the particular system.

A few mixtures need more than one set of vertices for satisfactory representation; some others have vertices so close to the axis that accuracy is difficult to achieve on a chart of small size. A few examples of each appear in this compilation.

Table 1. Coordinates of vertices.

High boiler	P., atm.	*Liquid* Lx	*Liquid* Ly	*Vapor* Vx	*Vapor* Vy
LOW BOILER: ACETONE					
Acetic acid, x≤ 0.53	1.0	252	245	925	372
Acetic acid, x> 0.53	1.0	252	245	947	489
Benzene	1.0	262	500	630	365
Butanol	1.0	090	196	933	293
Chloroform	1.0	639	409	632	812
Ethanol	1.0	568	799	827	324
Methanol	1.0	553	452	662	247
Methyl cyclohexane	1.0	485	334	782	288
Monochlorbenzene	1.0	841	406	957	039
Toluene, x≤ 0.15	1.0	150	154	660	113
Toluene, x> 0.15	1.0	500	385	940	108
Trichlorethane	1.0	268	330	957	281
Water	1.0	047	383	685	088
Water	6.8	048	370	670	070
LOW BOILER: METHANOL					
High boiler					
Benzene	1.0	201	111	570	009
i-Butanol	1.0	1070	870	1044	160
1, 4 Dioxane, x≤ 0.75	1.0	205	250	848	052
1, 4 Dioxane, x> 0.75	1.0	050	200	710	058
Ethanol	1.0	470	347	663	342
Water	1.0	153	405	751	234
Water	4.0	243	178	721	118

ACKNOWLEDGMENT

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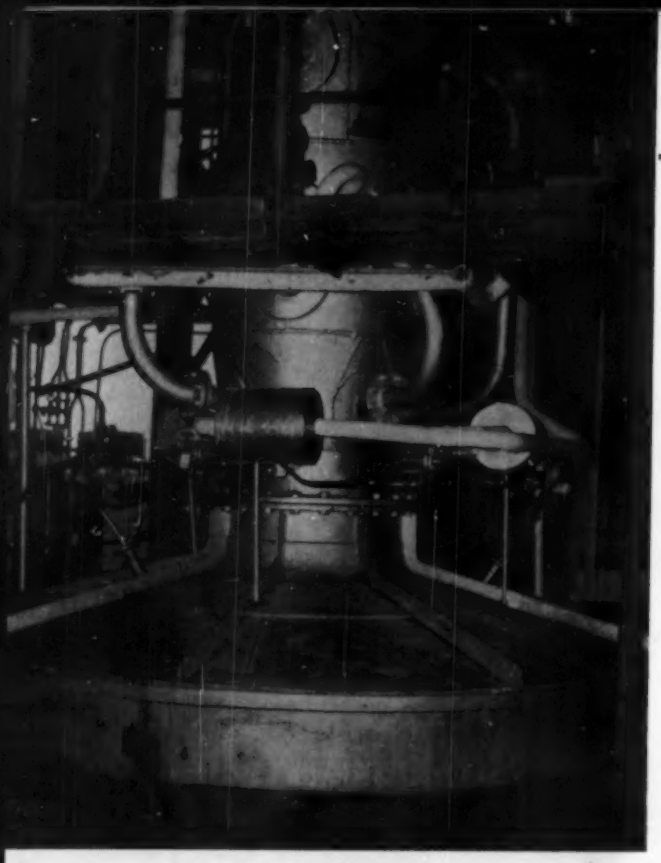


TOSHIO TANIYAMA, YOSHIICHI KARATO
Sumitomo Chemical Co., Ltd.

Coal gasification —Sumitomo process

Japanese design and operational acumen breach technical barriers in the path of commercial coal gasification.

NOT TO BE OUTDONE BY SEVERAL other countries throughout the world already gasifying middle- and low-grade coals, Japan has also climbed on the bandwagon. The key points of a coal gasification process developed by the Sumitomo Chemical Co. involve a ferrous oxide flux and a vertically-rising vortex entrainment.

The method is a normal pressure gasification in which a mixture of pulverized coal, oxygen, and steam is jetted diagonally downward into the gasifier from the lower part of vertical cylindrical furnace and from which slag is efficiently separated by an upward vortex current, collected at the bottom of the furnace, and discharged at comparatively low temperature, Figure 4.

A pilot-plant scale gasification unit was completed by the end of 1954, and a new 50 ton coal/day industrial unit was constructed in 1955 which was successfully operated continuously for 3000 hours in 1956.

Effect of flux on slag

It is of course desirable to gasify pulverized coal under the optimum condition, viz. ash content of the pulverized coal is fused at 1200-1300°C of gasification temperature for smooth discharge and disposal. However, difficulty is to be anticipated in achieving smooth discharge and disposal under this condition without using flux, regardless of the kind of coal used. Therefore, what is proposed here is to lower the melting point of the slag and increase its fluidity by using a flux. FeO is a good flux in that it can lower the melting point of the silicic acid in the slag.

The lowest melting temperature of the eutectic mixture of FeO-SiO_2 is 1115°C. There are difficulties in its use because in the conventional gasification method FeO is reduced by carbon to iron and may sometimes be oxidized or sometimes reduced according to the property of the atmosphere. However, if pulverized coal is gasified on entrainment, it is possible, by controlling coal powder distribution and carbon powder density in the vortex, to induce either the oxidation or reduction reaction of FeO by the generated gaseous atmosphere instead of its direct reduction by carbon.

The control of oxidation or reduction of FeO by the generated gaseous atmosphere can be achieved by adjusting the amount of steam added to maintain the water gas conversion reaction in the state of equilibrium.

That is, oxidation and reduction of FeO by the producer gas atmosphere in the gasifier is governed by the following equations:

$$FeO + CO \rightleftarrows Fe + CO_2 \quad \ldots . K_1$$
$$FeO + H_2 \rightleftarrows Fe + H_2O \quad \ldots . K_2$$
$$CO + H_2O \rightleftarrows CO_2 + H_2 \quad \ldots . K_3$$

Therefore, if the values of the ratios among the four compounds of the produced gas, viz. CO_2/CO and H_2O/H_2, are made larger than the equilibrium constants K_1 and K_2 of the water gas reaction by adjusting the amount of steam to be added, then production of iron in the gasifier will be prevented so that the total amount of FeO can be made to react as flux on SiO_2.

Thus, the relation between the temperatures of oxidation and reduction of FeO by the four compounds CO, H_2, CO_2, and H_2O and the gas

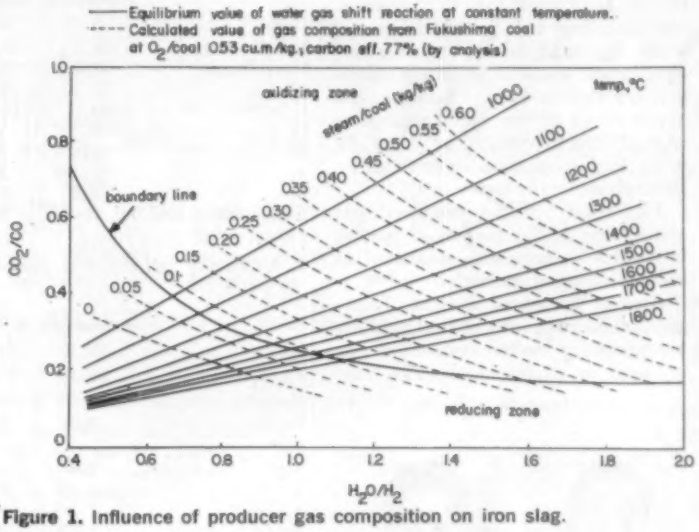
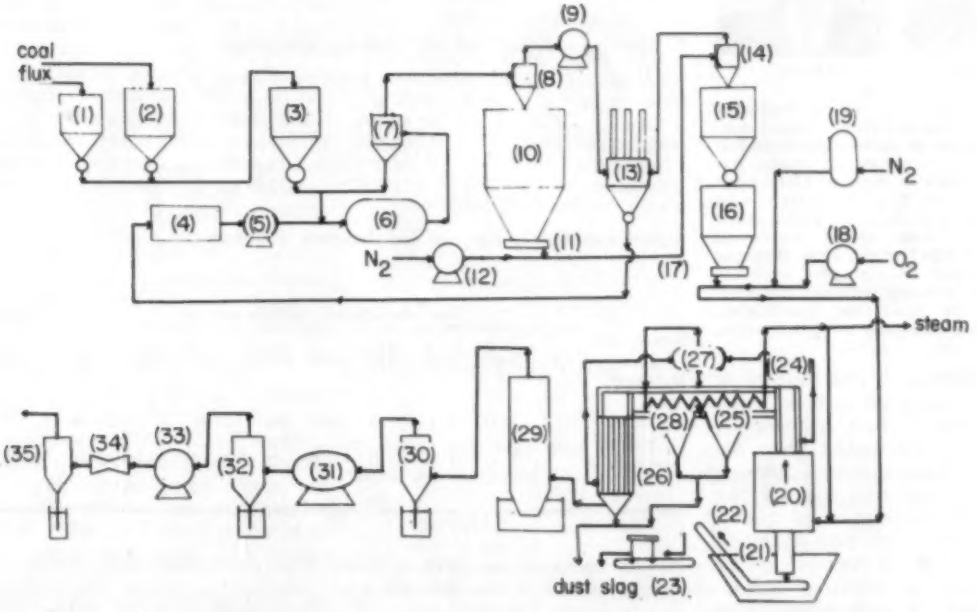


Figure 1. Influence of producer gas composition on iron slag.



(1) flux bin
(2) raw coal bin
(3) mixed coal bin
(4) hot air furnace
(5) hot air fan
(6) pulverizer
(7) 1st separator
(8) 2nd separator
(9) exhauster
(10) pulverized coal bin
(11) screw feeder
(12) N_2 compressor
(13) bag filter
(14) cyclone separator
(15) coal weighing hopper
(16) coal feed hopper
(17) coal feeder
(18) O_2 blower
(19) N_2 reserver
(20) coal gasifier
(21) slag removal tank
(22) slag flight conveyer
(23) slag weighing conveyer
(24) 1st jacket boiler
(25) 2nd jacket boiler
(26) waste heat boiler
(27) steam accumulater
(28) steam super heater
(29) cooling tower
(30) cyclone scrubber
(31) Theisen washer
(32) mist separator
(33) gas blower
(34) Venturi scrubber
(35) mist separator

Figure 2. Gasification plant flow sheet.

composition ratios, is calculated from the equilibrium constants given by (*1*), as shown in Figure 1.

In Figure 1, the straight lines indicate the equilibrium value of the $CO + H_2O \rightleftarrows H_2 + CO_2$ reaction corresponding to each temperature, while the solid curve indicates the equilibrium value of oxidation-reduction reaction to FeO. Therefore, the upper range of the curve represents an oxidizing atmosphere against FeO, while the lower range is a reducing atmosphere.

The ability of the produced gas atmosphere at the bottom of gasifier to oxidize or reduce is estimated as in the following example:

Assume the added amount of oxygen is 0.53 cu. m./kg of coal, and the corresponding carbon conversion rate is found by analysis to be 77%, then

Taniyama

Karato

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Yoshiichi Karato joined Sumitomo Chemical in 1947, right after finishing Meiji Technical College. His work on gasification research includes commercialization of the coal gasification process and, currently oil gasification.

gas compositions at the bottom of gasifier are computed as their equilibrium values at each temperature, as shown by the dashed lines. Accordingly, the atmosphere is reducing if the steam/coal ratio is 0.1 kg/kg with bottom temperature of gasifier of 1400-1500°C; then Fe is produced. Moreover, since the boundary condition between the oxidizing and reducing ability of gas composition on FeO in the upper part of the gasifier is $CO_2/CO \leqq 0.32$ and $H_2O/H_2 \leqq 0.85$ at 1200°C, and $CO_2/CO \leqq 0.27$, $H_2O/H_2 \leqq 0.9$ at 1350°C, the optimum condition for adding steam is within a limited range such as 0.3-0.4 kg/kg of coal, in the case of pulverized coal gasification.

Gasification equipment

A brief description of the gasification process successfully put into commercial operation in 1956 is given here. Figure 2 is the flow sheet of the coal gasification equipment including the gasifier. The instrumentation diagram of the process is given in Figure 3.

As shown by Figure 4 and Table 1, the gasifier is a vertical cylinder three meters high, completely lined with silicon carbide bricks; 1.5 meters I.D. to a third of the way up, and 2 meters I.D. for the upper two-thirds. The lower third is protected with a water-cooling box.

Four burners are arranged symmetrically around the bottom of the cylinder and the mixture of pulver-

Table 2. Characteristics of raw material and product material.

1. Analysis of coal and dust from scrubber; weight–percent.

	Coal				Takamatsu coal (mixed 5% flux)	Dust from scrubber
	Fukushima	Saitozaki	Takamatsu	Matsuura		
H_2O	2.8	2.6	3.8	1.5	1.5	1.3
Volatile matter	34.7	34.7	33.0	35.55	33.8	1.9
Fixed carbon	41.4	33.9	33.3	37.70	35.9	45.6
Ash	21.1	28.8	29.9	25.25	28.8	51.2
C	60.8	55.6	51.4	58.21		
H	4.3	4.1	4.1	4.32		
O	9.5	8.1	9.6	7.92		
N	1.3	0.6	0.9	1.12		
S	0.2	0.2	0.3	1.68		
Gross calories, kcal./kg.	6060	5560	5140	5600		

2. Analysis of coal ash, flux, and slag; weight–percent.

	Coal ash				Pyrite cinder	Matsuura slag
	Fukushima	Saitozaki	Takamatsu	Matsuura		
SiO_2	53.70	53.40	56.26	53.93	7.2	48.04
Al_2O_3	26.18	23.18	27.81	20.56	1.5	15.80
CaO	0.63	0.56	0.07	5.14	0.9	4.18
Fe_2O_3	6.99	8.82	4.35	8.87	88.5	2.32
FeO	....	....	....	....	....	25.00
MgO	2.66	1.63	1.90	1.55	1.2	1.50
S	0.85	0.63	0.46	1.25	0.6	0.16
K_2O	1.26	1.56	1.74	1.98	....	....
Na_2O	1.63	1.78	1.62	1.06	....	....
Free Fe	....	....	....	....	....	0.06
Total Fe	4.9	6.17	3.05	6.20	62.0	18.76

3. Softening point of coal ash (reducing atmosphere).

Coal name	Weight-percentage of pyrite cinder in ash			
	0	10	20	30 (%)
Takamatsu	1450°C	1350°C	1150°C	1100°C
Matsuura	1260°C	1150°C	1120°C	1110°C
Fukushima	1220°C	1120°C	1110°C	1090°C
Saitozaki	1180°C	1130°C	1120°C	1100°C

4. Screen analysis of raw coal and dust from scrubber.

	Size distribution (weight-percent)									Weight mean diam. of particle
Screen size (mesh)	+10	+20	+32	+42	+60	+100	+150	+200	−200	(mm.)
Matsuura coal + flux	1.0	8.0	6.4	14.8	11.2	10.4	15.6	3.2	29.4	0.32
Dust of scrubber	..	1.0	0.4	10.0	0.9	3.4	13.6	17.4	62.3	0.09

Table 1. Outline of Sumitomo pulverized coal gasification.

Capacity (coal)	2 ton/hr.
Generated gas volume (wet base)	4000 Nm^3/hr.
Jet velocity of gasification reactants	100 m./sec.
Diameter of gasifier	2 m.
Diameter of gasifier outlet	0.5 m.
Height of gasifier	3 m.
Retention period of generated gas	1.7sec.
Ascending gas velocity inside gasifier	1.9 m./sec.

ized coal, oxygen, and steam is blown tangentially and diagonally downward into the gasifier to preclude any dead space of the current at the hearth. The current of mixed materials strikes against the slag, stirs it, and thereby makes the flux more effective. The side brick wall of the gasifier is protected by the cooled slag itself. This feature, together with the effect of water cooling, maintained the brick life of the commercial unit for more than 3000 hr. of continuous operation.

The generated gas is led through an outlet at the center of the gasifier roof, and sent to the waste-heat recovery. The whole inner surface of the gasifier, including the gas outlet, is made "wet wall" with the slag held molten. Thus, the generated gas containing molten dust, can be taken out without difficulty for a long time. Overflow slag from the outlet at the center of the earth is continuously discharged and broken by water jet.

Results of gasification

To determine what kinds of coal can be used as raw material, the four kinds of middle- and low-class coals shown in Table 2 were put to a gasification test in a small test furnace. It was confirmed that their ash could be easily slag-tapped. Based on this result, the most economically available Matsuura coal was selected for the continuous commercial operation.

Size of the coal was (as shown in Table 2, 4.) 0.32 mm. in weight-mean diameter, and pyrite cinder was mixed as flux equal to 5% of the coal.

The typical examples of gasification results are given in Table 3, while the relation between the oxygen/coal ratio and the CO + H_2 coal ratio is shown in Figure 5.

Regarding the addition of ferrous oxide as flux, if FeO/SiO_2 is about ⅔ as shown in Table 2 (Composition of slag), the discharge and disposal of liquid slag are easily carried out when the temperature of generated gas is 1200°C. Therefore, the ratio need not be more than 5% as against coal.

Regarding the steam/coal ratio, gas compositions in the gasifier in the cases of dry gas and wet gas are as shown in Table 5.

Therefore, regarding the critical condition of ability of the gas to oxidize or reduce iron inside the gasifier, or for the data of Table 6, the gas composition in the furnace is reducing to iron at the upper part of the gasifier and oxidizing to it below the middle of the gasifier where the carbon conversion rate is below 90%.

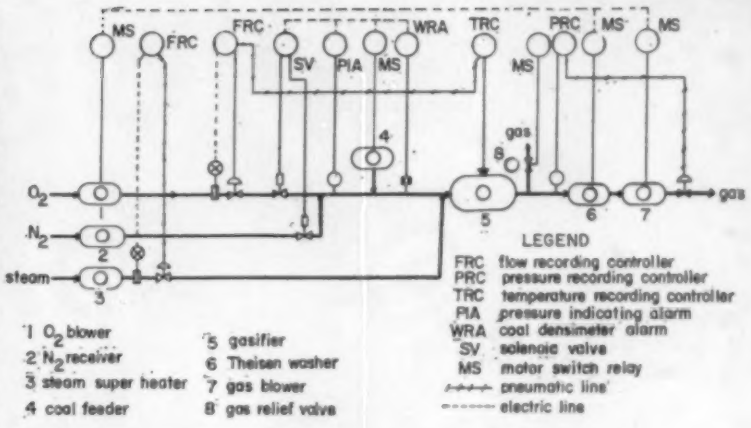

Figure 3. Schematic layout of automatic control system for gasification plant.

Table 3. Principal operation results on Sumitomo gasification plant (Matsuura coal)

Feed rate of raw coal, kg./hr.	1820	1910	1870
Process oxygen input (100%), (N)cu. m./hr.	882	980	1010
Process steam input, kg./hr.	553	626	690
Product gas output, (N)cu. m./hr.	2880	3120	3090
Product CO + H_2 output, (N)cu. m./hr.	2450	2650	2590
Product slag output, kg./hr.	345	387	402
Outlet gas temp. of gasifier, °C	1210	1255	1310
Oxygen/raw coal (100% oxygen), (N)cu. m./kg.	0.485	0.514	0.541
Process steam/raw coal, kg./kg.	0.304	0.328	0.369
Product gas/raw coal, (N)cu. m./kg.	1.580	1.630	1.650
Product CO + H_2/raw coal, (N)cu. m./kg.	1.343	1.387	1.385
Carbon efficiency, %	92.1	97.2	98.9
Thermal efficiency, (Heat of combustion of prod. gas per coal feed), %	73.7	75.9	75.8
Percent of H_2O decomposition based on process steam and H_2O in coal, %	39.8	36.5	35.1
Percent of slag collected in gasifier, %	65.7	70.3	74.3
Analysis of gas produced, by volume			
CO_2, %	11.7	12.1	13.0
CO, %	51.1	52.1	51.9
H_2, %	33.9	33.0	32.2
CH_4 + illuminant, %	0.6	0.5	0.4
O_2, %	0.2	0.2	0.2
N_2 + impurities, %	2.5	2.1	2.3
CO + H_2, %	85.0	85.1	84.1
Calorific value (gross) kcal./(N)cu. m.	2616	2611	2574

Table 4. Heat balance of gasifier.

Basis: Matsuura coal 1 kg., O_2/Coal = 0.514 (N) cu. m./kg., 0°C 1 atm.

Input	Kcal./kg. coal	Percentage
Gross calorific value of coal	5600	100.00
Sensible heat of coal	8	0.14
Sensible heat of process oxygen	4	0.07
Sensible and latent heat of process steam	246	4.40
Total heat	5858	104.61
Output:		
Gross calorific value of dry product gas	4250	75.85
Sensible heat of dry product gas	740	13.25
Latent and sensible heat of unreacted steam	324	5.79
Gross calorific value of residue carbon	133	2.38
Sensible heat of residue dust and slag	113	2.02
Heat loss from gasifier	298	5.32
Total heat	5858	104.61
Heat recovery system; (Heat of product steam from waste heat boiler)		
Heat of process steam	246	4.40
Heat of credit steam	379	6.77
Total heat	625	11.17

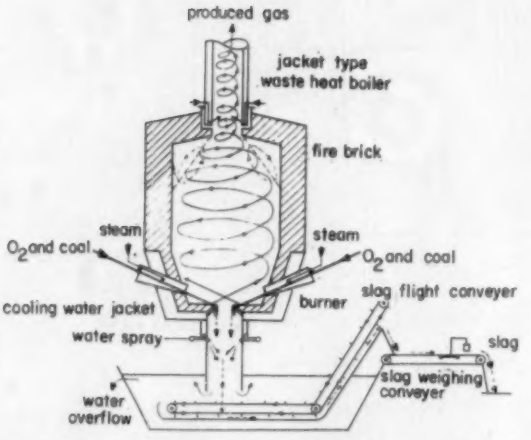

Figure 4. Sectioned view of gasifier furnace and slag removal conveyor.

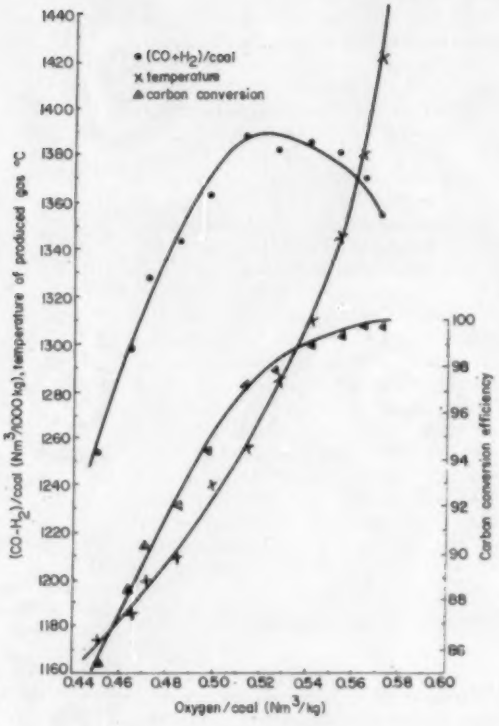

Figure 5. Results of gasifier operation as a function of oxygen-carbon ratio.

Thus, the selection of steam/coal ratio is determined within such range that the gas composition in the gasifier is kept oxidizing to iron, avoiding the inclusion of pig iron in the molten slag to be discharged.

The relation between the particle size distribution of pulverized coal and scrubber dust mentioned in Table 2, and the slag collection rate and carbon conversion efficiency mentioned in Table 3 is governed by design conditions of the gasifier. For example, when the particle size of pulverized coal is:

more than 0.5 mm.; less than 20%

less than 0.1 mm.; less than 30%

and the gasifier is so designed that the minimum size of particle going out of outlet is 0.08 mm., the following results were obtained:

Slag collection rate	73-75%
Carbon conversion efficiency	92-99%
Maximum diameter of scrubber-dust particles	0.1-0.15 mm
Average particle diameter	0.09 mm

The heat efficiency of gasification, as seen from Table 4, is as follows: The calorific value of produced gas is 75.8% of that of coal, and the sensible heat of produced gas and undecomposed steam is 16.4%, total. Thus, since the recovery of waste heat is possibly 11.0%, the total heat efficiency of the gasification equipment is 85%.

The radiant heat loss of the gasifier is 300kcal./kg. of coal, while the radiant heat loss from the water cooling jacket (at the protective part of wall of the lower part of the gasifier) is 65%, but this is the inevitable radiation to protect the lining of fireproof brick.

If the heat absorbed by the water cooling jacket is recovered for preheating water to generate steam, then the total heat efficiency is raised by 3.5% up to 88.5%. The dust content at each dust collector is as shown in Table 7.

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Table 5. Gas composition in gasifier, percent.

	Upper part of gasifier		Middle part of gasifier	
	Dry gas	Wet gas	Dry gas	Wet gas
CO_2	12.1	10.0	14.5	11.3
O_2	0.2	0.2	0.2	0.2
CO	52.1	43.3	50.7	39.4
H_2	33.0	27.4	31.7	24.6
CH_4	0.5	0.3	0.5	0.4
N_2	2.1	2.0	2.4	1.8
H_2O	..	16.8	..	22.3
CO_2/CO	..	0.231	..	0.287
H_2O/H_2	..	0.613	..	0.907
Temperature, °C	1255		1350	

Table 6.

CO_2/CO	H_2O/H_2
1255°C	
oxidizing $>$ 0.305	oxidizing $>$ 0.87
1350°C	
oxidizing $>$ 0.27	oxidizing $>$ 0.90

Table 7. Dust content.

	Dust content, g./cu.m. (gas)
Outlet of gasifier	69
Outlet of scrubber for cooling	14.17
Outlet of cyclonic scrubber	1.13
Outlet of Theisen washer	0.032
Outlet of gas blower	0.017
Outlet of Venturi scrubber	0.010

C. M. SCHWARTZ
Battelle Memorial Institute

Ultrahigh pressure technology

Synthesis of new materials having unique properties and the opportunity to explore geochemical and geophysical processes are becoming feasible with the rapid laboratory development of high pressures and temperatures.

THE RAPIDLY DEVELOPING FIELD of superpressure offers great potential as a tool in chemical technology. There appear to be two major objectives: one, to obtain a basic understanding of the effects of pressure on matter; and two, the search for applications of pressure as a new tool in materials research and synthesis.

To provide suitable orientation, the pressure range of interest and its relation to the gamut of pressures existing in the universe must be established. If we examine the pressures of geophysical and astrophysical origin, we find an extreme range, from the near perfect vacuum of space to the pressures at the centers of the heaviest stars. On earth, the pressure at the bottom of the deepest ocean trench is about 1000 atm.; at the inner edge of the earth's crust (*i.e.*, the Mohorovicic discontinuity between crust and mantle), 10^4 atm.; and at the boundary between mantle and core, 10^6 atm. At the earth's center the pressure is about 3.6×10^6 atm.; at the center of the sun, 10^{11} atm.; whereas, within the white dwarf stars the extraordinary pressure of 10^{17} atm. may be reached.

Such extreme values cannot, of course, be attained in the laboratory. The highest pressure reported in a static experiment is 4×10^5 atm., while in explosive shocks transient pressures over 10^6 atm. may well have been reached. However, the difficulties involved in measuring pressure and temperature during the short time of passage of the shock wave through

High pressure tetrahedral-anvil apparatus with one anvil retracted.

. . . Pressure, as another degree of freedom, may be capable of producing new phases that do not undergo phase transitions at high temperatures.

the sample being investigated, and the uncertainty as to attainment of equilibrium, make this method somewhat less attractive for materials research; therefore, shock-wave studies will not be considered. It is evident that we should seek ultimately to reach static laboratory pressures up to 10^6 atm. if we are to simulate geological processes.

Effects of pressure on systems

In considering the fundamental effects of pressure, there are several rules that qualitatively control the behavior of the system under investigation. One is the well-known principle of Le Chatelier, involving the factors affecting equilibrium in reversible processes. Thus, reactions involving condensible systems are governed by the system pressure which, if increased, acts as a driving force shifting the equilibrium in the direction of decreased volume.

There is evidence, as well, of the effect of pressure on condensed systems. Thus, compressibilities are always positive, and if a phase change occurs under pressure, the principle predicts that increased pressure will shift the transition in the direction forming the phase of lesser volume. For example, all gases or liquids will solidify at room temperature under sufficient pressure. In the case of the most difficult gas to freeze, helium, the pressure is estimated at about 10^5 atm.

What will happen to crystalline solids which are normally stable up to high temperature without undergoing phase transitions? In the case of most metallic or mineral systems, composition and temperature are the two variables usually considered in carrying out phase-diagram studies. Considerations of thermodynamics and the phase rule, however, indicate that pressure as another degree of freedom may be capable of producing new phases, with implications of great significance. Knowledge of the atomic structure of solids should provide some clues as to their behavior under pressure. In solids the bonds are stronger, the densities are generally higher than those of gases or liquids, and higher pressures are needed to cause transformations. Nevertheless, the compressibility of solids, though small, is finite and measurable. Furthermore, where polymorphism is known, the high temperature stable form is generally the more symmetrical structure and consequently its atoms are more closely packed. Since increasing pressure favors the phase of higher density, it might be possible in this way to transform some solids into more dense forms not observed in nature. In fact, it seems likely that all materials will transform ultimately into close-packed metallic structures at high enough pressures. The attainment of more symmetrical structures through increased pressure is simply an example of the second principle governing system behavior, namely that of structural order.

As a corollary effect, it may be expected that pressure will reduce thermal vibratory and rotatory motion and consequently will oppose the effects of temperature upon the energetics of the reaction. Thus, pressure should have an effect, not only on equilibrium conditions, but also on reaction rate. In the case of solids with ionic or covalent bonding, the effect is to increase bond strengths and thus lower the reactivity. On the other hand, raising the temperature has the opposite effect on bond strength, owing to the increased thermal vibrations and separation of the atoms or ions. This increases the chemical reactivity and thus counteracts the effect of pressure. In fact, most reactions, as in the synthesis of diamond, would be much too sluggish at room temperature to be of economic value, and thus the use of heat simultaneously with pressure appears mandatory. This requirement imposes a severe restriction on the design of ultrahigh pressure apparatus as will be apparent in the later discussion of apparatus and techniques.

Assuming that pressure causes phase transformations as predicted, there remains the question of the stability of any newly formed phase and its possible reversion to that form which is thermodynamically stable at

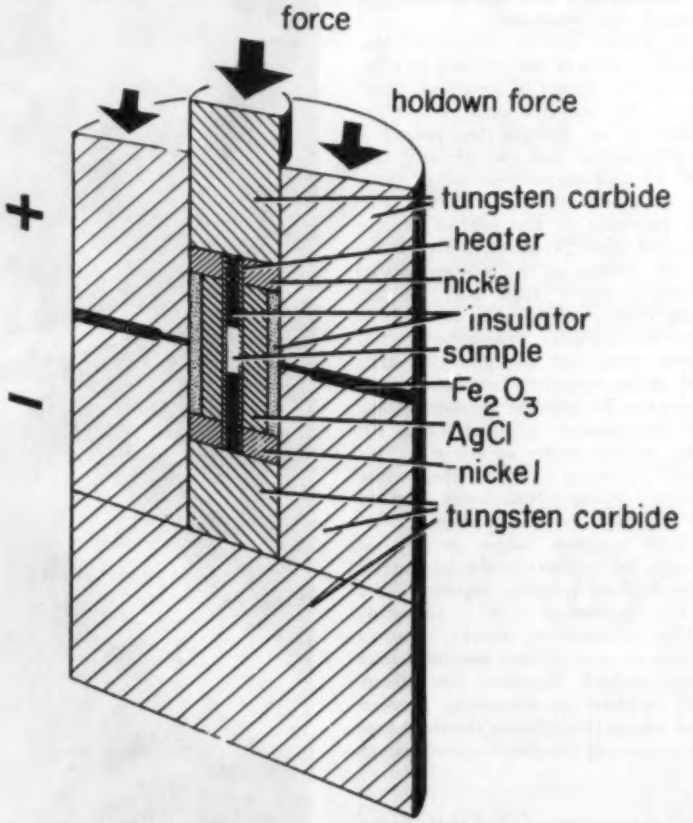

Figure 1. Interior of high-pressure cylinder die with electrical heating.

low pressure. Although most phase transformations are reversible with temperature change, fortunately there are many transformations known to be so very sluggish that if the high-temperature form is cooled with sufficient speed it is retained in a metastable condition. The diamond is a classical example; it is metastable and reverts to graphite on heating. However, this reverse transformation is exceedingly slow, and diamond is normally considered a relatively stable material. Thus, there is evidence that high-pressure phases, once synthesized, would exist metastably over a useful temperature range for a sufficient time to be of use in some applications.

Ultrahigh pressure apparatus

Pressure reactors for laboratory synthesis up to a few thousand atm. are well known. Large scale applications in the petrochemical and plastics industries rarely exceed 1500 atm. owing to practical limitations of strength of the pressure vessels. Extrusion-press capabilities are now approaching a few thousand atm. Both laboratory and large scale chemical reactors generally use gas or liquid media for pressure transmission. Liquid transmission has been used up to 30,000 atm. where the best fluid, n-pentane, freezes at room temperature. Above this limit, other schemes have had to be developed.

The impetus for the present high-pressure research activities is due to the extensive and pioneering efforts of P. W. Bridgman. His early work employed the right circular cylinder vessel and piston. This extremely simple design might be expected to be limited by the bursting pressure of the cylinder. Calculations based on elastic theory would indicate that the pressure in a thick cylinder cannot exceed its tensile strength; nevertheless, Stillman in 1900 showed that a pressure of 25,000 atm. could be attained in a thick cylinder of steel with an ultimate tensile strength of 10,000 atm. Bridgman suggested that the inner layers of a cylinder are plastic at high pressures, thus distributing the stress over a greater area. Using an insert of cemented tungsten carbide, which is much stronger in compression than steel, he employed the principle of the compound cylinder in which outer binding rings are shrunk on or forced on by means of a conical fit so as to place the inner cylinder in compression. With this apparatus, he consistently obtained nearly 50,000 atm., the limitation being the crushing strength of the unsupported portion of the carbide piston outside the cylinder. By surrounding the piston and cylinder with a liquid under hydrostatic pressure, he was able to reach 100,000 atm. at room temperature. However, apparatus using such a cascade principle is bulky, difficult to work with, and not easily amenable to modification for heating; thus, it is not commonly used at present.

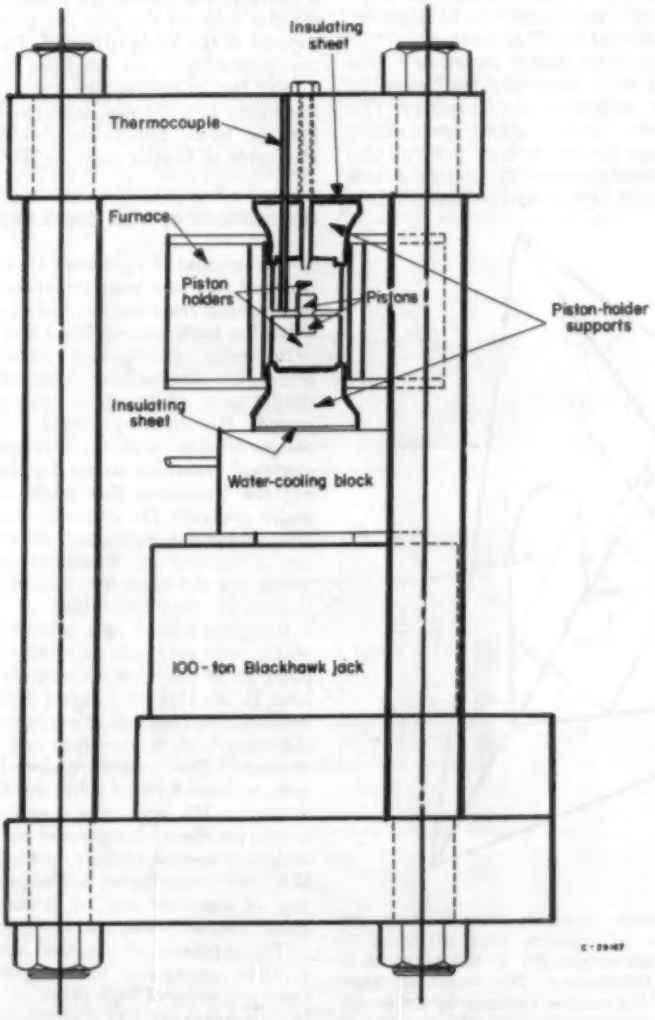

Figure 2. Battelle version of the Bridgman anvil high-pressure apparatus.

Figure 1 shows a cutaway drawing of the interior of a cylinder die employed at Battelle which has been modified to permit electrical heating. Heat is applied internally by means of electrical resistance heating in the following manner. The sample, in the form of a short rod, is encased in a thin-walled tubular resistor of graphite or platinum. The resistor is encased in a close-fitting, thick-walled insulating cylinder of unfired Grade A Lava. The die is water cooled. This design has performed satisfactorily up to nearly 50,000 atm. and at temperatures to 3000°C.

Another concept, that of massive support of the piston, was employed by Bridgman in his "anvil" unit. The Battelle version of this apparatus, Figure 2, consists simply of two abutting pistons of cemented carbide, with one or both working surfaces in the form of a flat truncated cone. The sample diameter, and thus the area of the pressure zone, is much less than that of the piston, so that binding-ring support is essentially provided over the entire length of piston. The sample is in the form of a thin disk, about 10 mils thick, placed within a compressible gasket ring of talc-like pipestone. External heat is supplied from a tube furnace surrounding the pis-

. . . Development of improved high pressure and temperature apparatus must keep apace with applied research to broaden over-all potentialities. Geochemical processes and chemical synthesis are now open to exploration.

tons. Pressures to 250,000 atm. have been obtained with this apparatus at room temperature. Temperatures up to 1000°C have been used, but owing to loss of strength of the die materials, the available pressure is not over 20,000 atm. at this temperature.

Despite the rather limited temperature range and the pressure restrictions imposed on heating, the Bridgman anvil has been used by a number of workers, especially in the field of mineral synthesis. It is highly attractive for laboratory use because of its extreme simplicity and low cost.

Diamond and Borazon were made by General Electric in special apparatus (the "belt"-conical die and piston with extruding gasket) maintaining about 100,000 atm. at temperatures up to 2000°C. H.T. Hall has described a fully supported die consisting of a compressed region in the shape of a regular tetrahedron, rather than cylinder or disk as in other known designs. Four pistons of cemented carbide, see introductory photo, are constrained by means of hydraulic cylinders which move along lines perpendicular to the triangular faces of the tetrahedron. The piston faces are triangular anvils and are beveled so as to nest together. Binding rings encase the carbide to support the tensile forces which develop. The sample is in a heater tube supported within a pyrophyllite tetrahedron, Figure 3, contained in the volume enclosed by the four anvils. The necessary motion for compression is provided by squeezing out some of the pyrophyllite into the space between the anvils. Internal electrical heating is employed. This is called the "tetrahedral-anvil" apparatus.

A new die design shown in Figure 4 has been developed and tested by W. B. Wilson of our laboratory. This die, the "girdle", shows considerable promise for use at high pressure and high temperature. It utilizes a new principle of motion via elastic distortion in which the pistons of the Bridgman anvil seat into an elastic steel die supported in turn by multiple binding rings. As the pistons are pushed together, the wedge effect of the cones forces the die to expand. The operative geometry is indicated in Figure 5. For pressure to build up in the die, the dimensions must be selected such that the volume decrease swept out as the pistons advance (disk volume = $\pi r^2 \Delta h$) must be larger than the expansion due to change in radius (annulus volume = $2 \pi rh \Delta r$). This die can be made with sufficient height to permit use of internal heating so that it offers all the advantages of the right circular cylinder die plus the massive support of the Bridgman anvil. Its full capabilities have not yet been ascertained, but in preliminary tests, pressures over 130,000 atm. were reached. Perhaps twice this value should be attainable at temperatures to 3000°C.

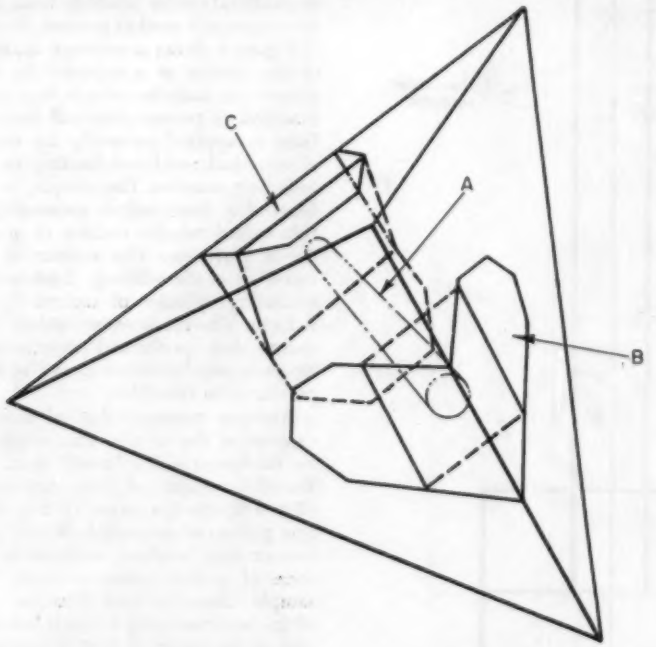

Figure 3. Schematic of sample-cell insert in the tetrahedral-anvil apparatus, consisting of the sample in the resistance heater tube A capped with metal end tabs B within the pyrophyllite tetrahedron. Pyrophyllite prisms C, cut out to permit insertion of A, are reinserted to fill the volume completely. Electrical contacts for heating are made to opposite pairs of anvils by end-tab extensions in the surfaces of the tetrahedron. The insert is larger than the volume enclosed by the anvils; on compression, excess pyrophyllite extrudes, forming a gasket seal.

Applications of high pressures

The promise of significant effects of pressure on phase transformations and on chemical reactions has been noted. What has been accomplished thus far?

Bridgman investigated numerous elements, intermetallic compounds, simple salts, and some organic compounds. His studies provided data on compressibility and on changes in electrical resistivity useful for detecting any transitions that might occur under pressure. He generally worked near ambient temperature, determining a number of transition points which are the basis for pressure calibration in other apparatus.

Bridgman's work was extended by others, with emphasis on synthesis. L. Coes, Jr. of the Norton Company and later H. T. Hall of General Electric, devised methods of simultaneously obtaining high temperature and high pressure. The former produced coesite, a dense form of silica, not found in nature. His apparatus consisted of a cylinder die of hot-pressed alumina with a cemented carbide piston. The G.E. work culminated in the production of diamond and of Borazon, a cubic form of boron nitride.

The synthesis of diamond marked a rather spectacular turning point in the application of high pressure, since it demonstrated the commercial potential of this research tool. Since

the density of diamond is considerably higher than that of graphite, many early attempts were made to employ heat and pressure in its synthesis, but with no success. Recently, based on a critical examination of the thermodynamic data for the transformation, it was concluded that diamond is the stable phase above 15,000 atm. However, Bridgman made several attempts to produce diamond with pressures above 100,000 atm. at room temperature. The reason for his failure, as we know now, was the slow rate of the reaction. Thus, the temperature must be raised to provide the necessary activation energy for rearrangement of the atoms. Heat, while supplying the activation energy, also causes disorder due to thermal motion of the atoms and molecules; thus, the equilibrium pressure for the reaction will generally rise to counteract the disordering effect of temperature. At 2000°C, therefore, over 70,000 atm. would be required according to the thermodynamic calculations.

The fact that diamond is a natural product was an obvious challenge to mans' ability to synthesize it. Borazon, however, does not occur in nature. It is of interest to note that its existence was predicted on the basis of a knowledge of the structure and properties of the ordinary hexagonal polymorph and the striking analogy to carbon. Hexagonal BN is soft and flaky like graphite. Easy slip occurs between the hexagonal platelets. The cubic form was predicted to have the structure and hardness of diamond; this material, when produced under high pressure, did have the predicted structure and hardness, but showed better oxidation resistance than diamond.

Coesite, with a density of 3.01 g./cu. cm. compared to 2.65 for quartz, was prepared from sodium silicate and a mineralizer at 35,000 atm. and 750°C. Similar conditions should be available in the earth's interior, so its nonexistence as a natural mineral might be explained on the basis of the relation of the cooling rate to the rate of inversion, or ascribed to secondary reaction. It is obvious that in the case of the products synthesized so far, the inversion to the stable state is sluggish enough to permit the metastable phase to persist on cooling.

A number of naturally occurring minerals, mostly siliceous, have been synthesized. These include sillimanite, jadeite, andalusite, kyanite, topaz, and pyrope. Clay is frequently one of the starting components; and since it contains water, one wonders whether the latter contributes to the reaction rate because of its high solvency for silica.

Several transitions have been studied in the field of organic chemistry with pronounced effects observed at modest pressures. For example, a shift in equilibrium between cis and trans 1,2-dichloroethylene was found, the shift with increased pressure being in the direction of the isomer of increased density. The change in equilibrium constant computed from the known molar volumes of the two forms at one atm. agreed well with the experimental change.

Nuclear reactor fuel synthesis

At Battelle we have been interested in pressure in two ways, both as a tool for synthesis and as a means of investigating basic properties of the solid state. In the area of synthesis, we have been concerned with the potential capabilities of pressure in the production of new materials, in particular, those materials of interest as nuclear reactor fuel elements. One of the most promising of these for high-temperature reactor service is UO_2. This is a stable refractory under neutral or reducing environment and is capable of forming a dense homogeneous ceramic body with excellent nuclear properties. It is

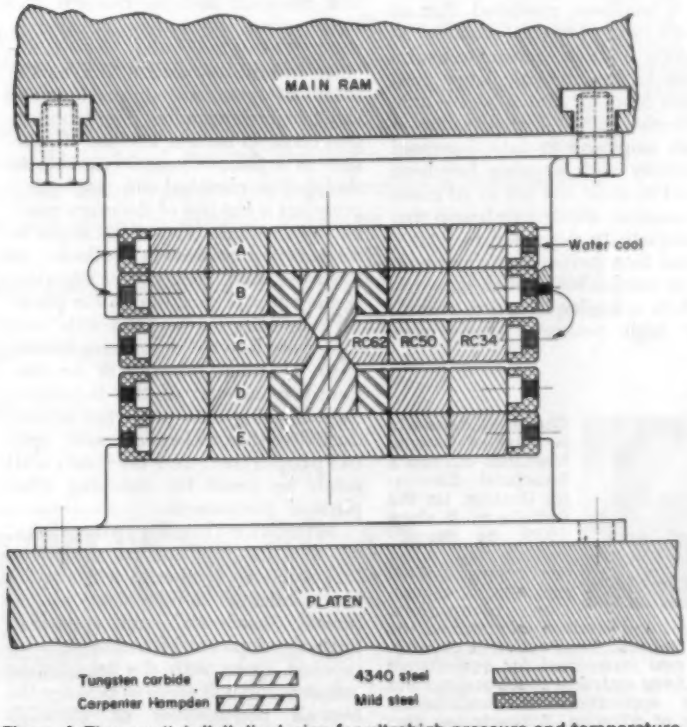

Figure 4. The new "girdle" die design for ultrahigh pressure and temperature.

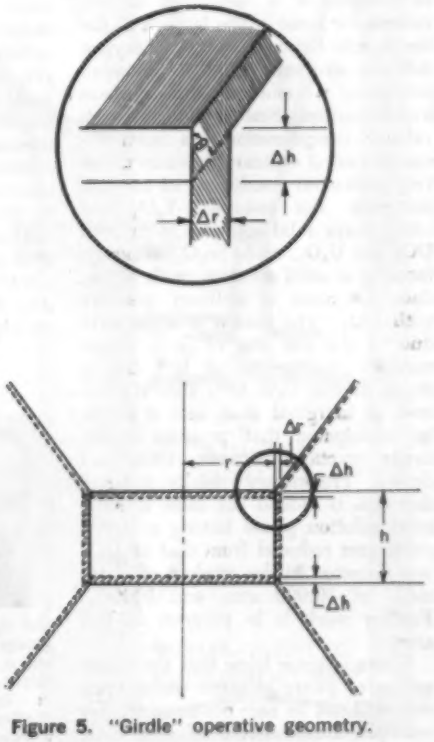

Figure 5. "Girdle" operative geometry.

unstable in an oxidizing atmosphere at elevated temperature, oxidizing to U_3O_8 with a marked increase in volume and consequent spalling. The U_3O_8 itself is not satisfactory for high-temperature reactor use because of its high volatility. Obviously, it would be desirable either to produce a new compound phase in which the uranium is hexavalent, or to stabilize the UO_2 fluorite structure by solid solution additive, to permit oxidation of the uranium without change in phase. Both methods have been tried at ambient pressure with limited success. Clearly, one should consider whether pressure, as another process variable, could assist in either method.

The effect of pressure in forming new compounds is being studied. For example, at ambient pressure BeO and either UO_2 or U_3O_8 do not form a compound phase; apparently the relative valence and ion sizes are not favorable. The possibility of this reaction at pressures to 50,000 atm. was tested without success. Experiments of this type, using component oxides with more favorable ion sizes, are being carried out at higher pressures in the new die assembly.

The possibility of stabilizing the fluorite structure of UO_2 against oxidation, by addition of other oxides in solid solution, is a very intriguing one which has been explored rather thoroughly. The principle involves substitution of a metal ion of low valence for some of the U^{+4} ion in the the fluorite lattice, forming an oxygen deficient structure in which oxidation can occur without subsequent phase transformation. Stabilization through valence compensation has been accomplished at ordinary pressure under very restricted conditions of ion-size matching. For example, Y_2O_3 and La_2O_3 form solid solutions with both UO_2 and U_3O_8, while Sc_2O_3, although forming a solid solution with U_3O_8, does not react at ordinary pressure with UO_2. The reason is apparently due to the ion size of Sc^{+3}, which matches closely that of U^{+6}, but is much smaller than U^{+4}. This is obviously a marginal case, and it might be anticipated that pressure would cause reaction between UO_2 and Sc_2O_3. Preliminary results indicate that this is indeed the case; a cubic solid solution phase having a lattice parameter reduced from that of UO_2 was detected in the product of a run made at 30,000 atm. and 1000°C. Further work is in progress in this area.

There is some hope that the observation of phase changes under pressure will not be rare occurrences. For example, a new modification of U_3O_8 has been obtained under pressure. Its crystal structure has not yet been determined although X-ray diffraction patterns have been obtained and analysis reveals its composition to be nearly stoichiometric U_3O_8. The new phase is metastable at room temperature.

Aside from applications to synthesis, high-pressure research has been employed effectively in studies of the properties of solids. Such studies have included the measurements of the effect of pressure on electrical conductivity, X-ray diffraction, nuclear magnetic resonance, and optical absorption of suitable materials. At Battelle we have started to measure the thermoelectric power and resistivity of semiconducting oxides in the pressure devices. Significant differences have been observed. An appreciable decrease in thermoelectric power with increased pressure was observed with NiO while no change occurred in Cu_2O. These differences are not explained; however, it is believed that pressure can induce changes in the form of a broadening of the electronic energy-band structure of the solid. The broadening would be expected to result in a decrease of the energy gap between the valence and conduction bands, and thus an increase in electrical conductivity.

According to theoretical calculations, it has been predicted that all materials will become metallic at sufficiently high pressure; for hydrogen and helium the calculated pressures are 5×10^5 and 2×10^7 atm. respectively. In the limited range of pressure employed to date, increased conductivity with pressure has been observed in some, but not in all cases. In germanium, Bridgman found that the conductivity decreased to 50,000 atm. and then increased, suggesting a complex mechanism. Other materials may show a similar inversion at sufficiently high pressure. Much more data are needed on the effect of pressure on the properties of solids to assist in a better understanding of the nature of the solid state.

Charles M. Schwartz is chief of Battelle Memorial Institute's Structural Chemistry Division. On the Battelle staff since 1939, he has directed studies on application of X-ray and electron-diffraction techniques, and light and electron microscopy. His group has also been active in developing a new instrument for quantitative micro X-ray emission spectroscopy, and in its application to fundamental studies of diffusion. Schwartz has also worked in high pressure research.

Conclusions

It is evident from the accomplishments to date that ultrahigh pressure should become an important tool in synthesis of new materials by promoting transformations and reactions in solids. As the pressure and temperature capabilities of the apparatus are improved, there is little doubt that new materials having unique properties will be synthesized. Under these conditions the new products should possess higher density, hardness or oxidation resistance. Therefore, we may hope for improved abrasives and refractories. There is also the possibility of development of new and exotic compounds or compositions for use as nuclear reactor fuels. In the field of organic, as well as inorganic, chemistry, the potentialities are equally promising. The utility of relatively modest pressures in producing parallel alignment and crosslinking has been well demonstrated; it is easily possible to project our reasoning to the discovery of stronger, denser, and harder plastics, and to the preparation of new and more complex compounds.

Geochemical processes will undoubtedly be explored thoroughly, and materials such as precious and semiprecious gems may be synthesized. Present indications are that another fruitful application will be the study of geochemical reactions to assist in understanding the processes that occur in nature. The use of pressure as a thermodynamic variable in studying geochemical and geophysical processes is but one of the many possible applications of this technique to fundamental studies, in particular, of the solid state. Indeed, investigations of the effect of pressure on the physical properties of the solid state may contribute heavily to our basic knowledge of solids. There will be continued refinement of the techniques for measuring such properties as conductivity, thermoelectric power, optical properties; and methods will surely be found for observing other physical phenomena.

All of the above applications, whether for fundamental studies or for chemical synthesis, will require the continued development of improved "hardware" and apparatus. Such development of technique must proceed apace with the applications research and will serve to broaden the over-all potentialities of ultrahigh pressure research.

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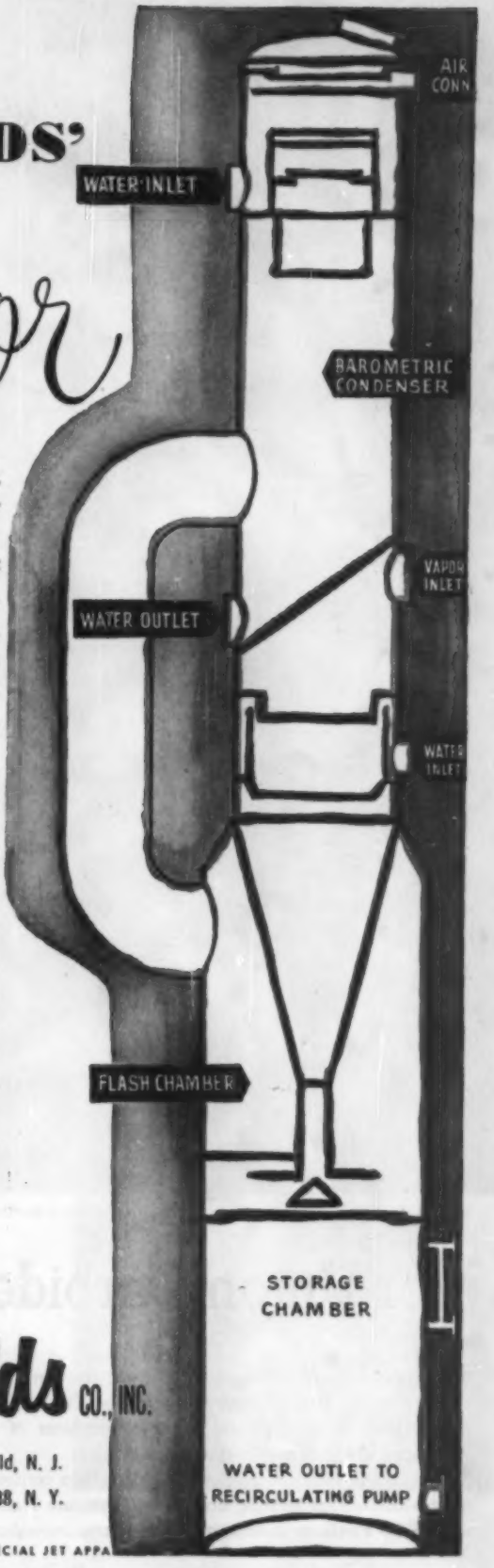
Patent applied for



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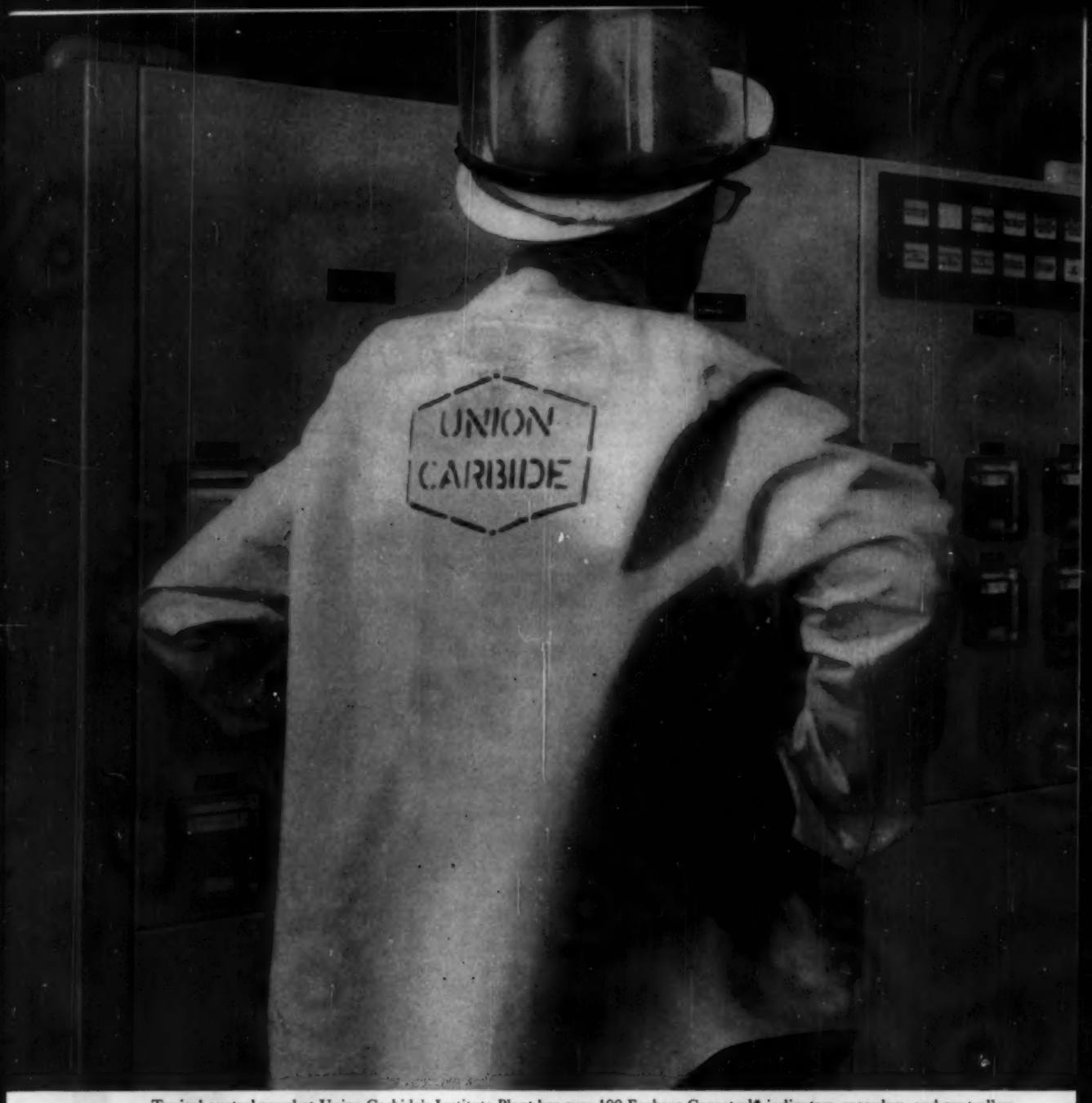

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A LARGE PRODUCTION-SCALE extrusion dryer of original design is now turning out low-ash SBR polymers at the Institute, West Virginia, plant of Goodrich-Gulf Chemicals. Under development since 1954, the 50-ton, 40-foot-long unit has a design capacity of 6,000-8,000 pounds per hour.

The new dryer, shown schematically in Figure 1, is powered by an 800 horsepower induction motor coupled through a clutch to a transmission which, in turn, powers a conical screw 4 feet long, tapering from a head diameter of 36 inches to a base diameter of 12 inches.

Wet crumb rubber from the leaching tanks passes over a vibratory screen, through a feed box, and into the conical screw section. This screw, operating at a maximum of 55.5 rev./min., pushes the wet rubber down the flights of the screw to an adjustable sliding cylinder valve. Under normal operating conditions, tolerances between the screw threads and the liner are held at 0.040 inch on each side. As the wet rubber is compressed by the conical-flighted screw at the valve, pressure builds up and the water is queezed out of the rubber. The water flows out through the opening in the bottom of the conical section, carrying with it the water-soluble salts. Approximately 80% of the total moisture content is squeezed from the crumb rubber in this 4-foot conical section, in which the cycle time is 2 minutes.

Vacuum chambers

Linked to the end of the tapered screw, and beyond the valve, is a straight, 12-inch diameter, 22-foot long multiflight screw which moves the rubber through a series of three vacuum chambers.

At the junction of the tapered screw and the main conveyor screw is an adjustable sliding-cylinder valve which adjusts the tolerances between the bevelled bearing surfaces of the conical screw at its discharge end and the bevelled surface of the sliding valve; this action regulates the pressure at which the rubber is worked. (The tolerance must be adjustable, so that the machine can process a variety of polymers). The rubber flows through the valve in a sheet equivalent in thickness to the valve settings.

On the main conveyor screw, the rubber is carried through the three vacuum chambers, where the remaining moisture is flashed off. When it leaves the last vacuum chamber, its moisture content is at or below the standard specification of 0.5%. The vacuum in all three chambers is held at or below 27 mm. Hg.

When the rubber leaves the last vacuum chamber, it is forced by the conveyor screw through a round pelleting die, which marks the end of the extrusion dryer. The outside of the die is swept continuously with a rotating, double-bladed knife which slices off the strands of dry rubber emerging from the die. The material is then cooled, baled, and readied for shipment.

Temperature control essential

The screw section is cored to per-

continued on page 82

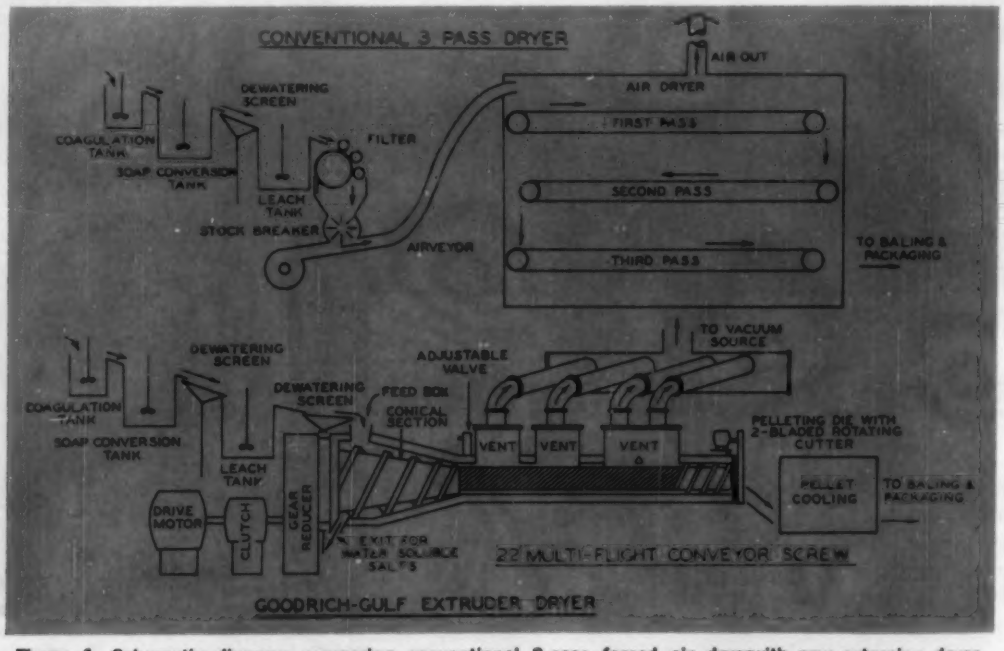

Figure 1. Schematic diagram comparing conventional 3-pass forced air dryerwith new extrusion dryer.

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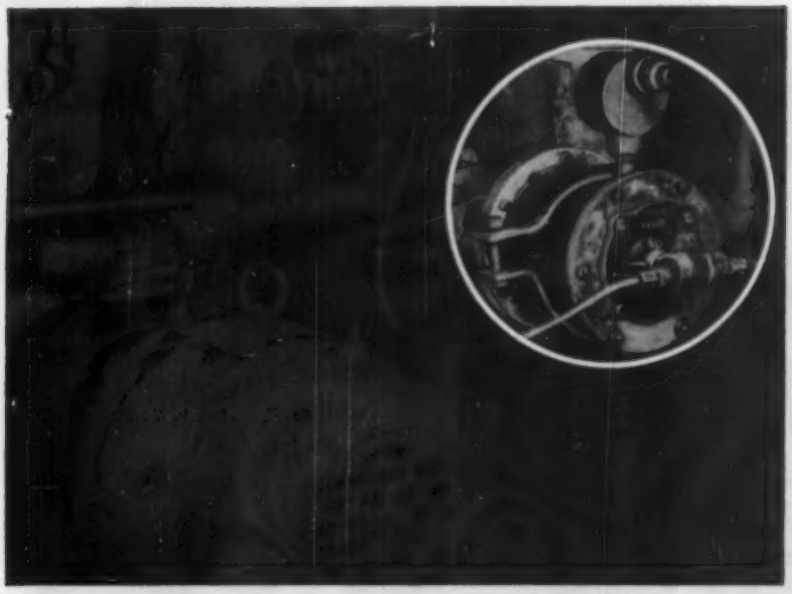

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Extrusion dryer

from page 80

mit heating and cooling; under normal conditions, maximum operating temperature of this unit is 220°F. In addition, the machine has several jacketed sections, so that temperature may be varied at different points in the process. The feed section is generally held at 140°F, while the temperature in the conical section varies from 150° to 200°F. The vacuum chambers are at 250°, while temperatures in the barrel and end sections drop to from 80 to 100°F.

Cycle time cut

Entire cycle time in the new unit, from the time the wet rubber enters the feed box until it passes through the pelleting die, is from 5 to 10 minutes. This contrasts with a cycle time of approximately 2 hours with conventional drying equipment based on a three-pass hot air dryer (also illustrated in Figure 1).

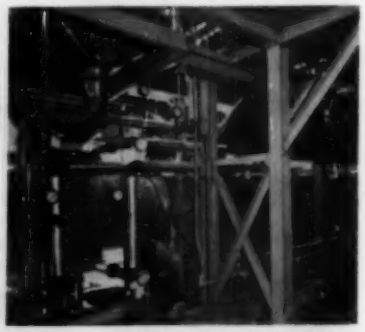


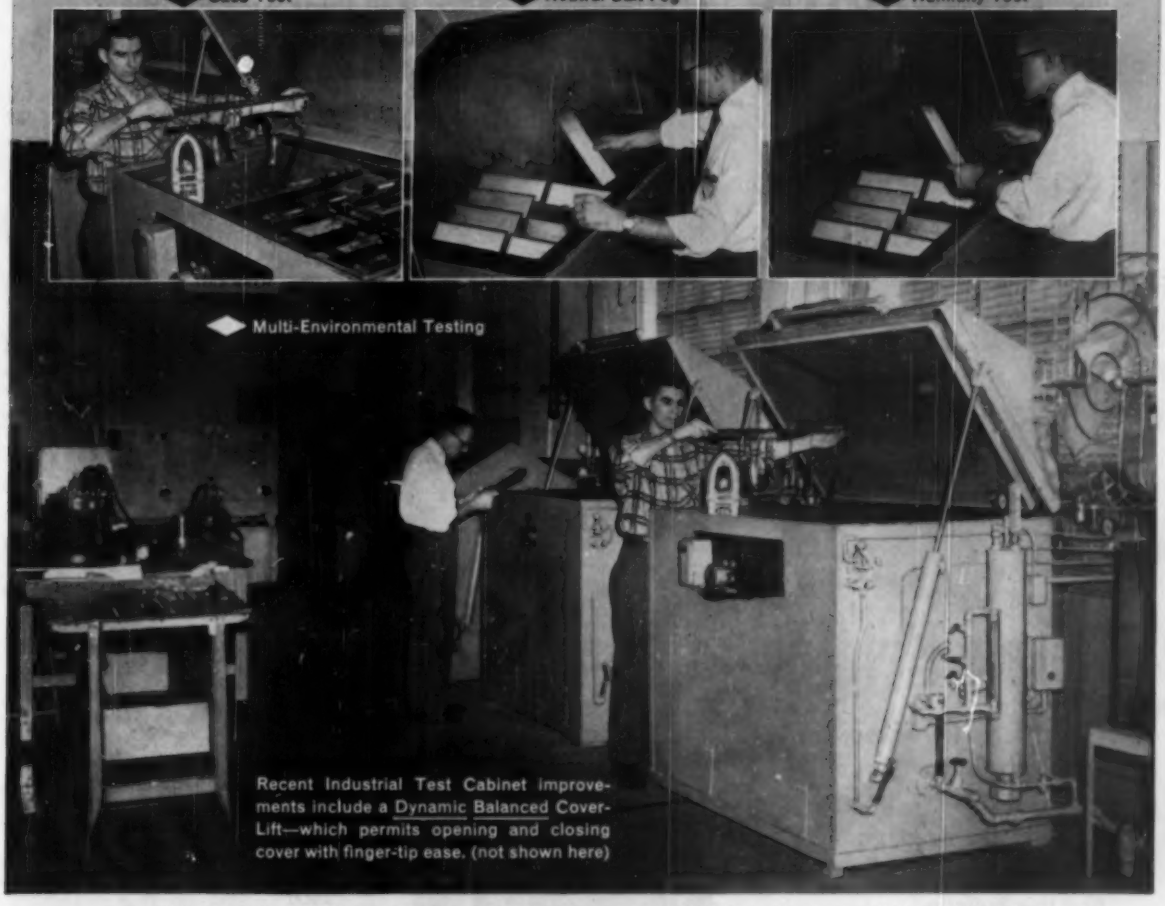
Figure 2. Side view of extruder dryer showing dewatering screen and crumb trap.

Further advantage claimed for the new method is low ash content in the finished product. When drying is by evaporation, as in the conventional process, the amount of inorganic impurities in the product remains comparatively high, often making the polymer unsuitable for electrical, adhesive, and other specialty uses. Ash in polymer is said also to affect cure rate, water sensitivity, and insulating properties.

Market potential

While the new drying unit at Institute is in regular production, Goodrich-Gulf still describes it as in "an advanced stage of development," does not yet regard extrusion drying as a replacement for air drying in all applications. Much work, according to the company, remains to be done in the area of customer evaluation of extrusion-dried SBR.

American Motors Fights Corrosion with INDUSTRIAL Test Cabinets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Multi-Environmental Testing
Recent Industrial Test Cabinet improvements include a Dynamic Balanced Cover-Lift—which permits opening and closing cover with finger-tip ease. (not shown here)

Rigid accelerated corrosion tests show reliability of Type 411 Cabinets

Corrosion resistance comes under conscientious control at American Motors. Typical of their emphasis on serviceability and long life for the RAMBLER product is their attention to the environmental testing of plated and painted parts.

Among recent test equipment additions to their production test facility at Kenosha, Wisconsin, were three of our new Type 411 Corrosion Test Cabinets. Particularly suitable for this auto manufacturer's needs, Type 411 is versatile enough to meet all the essential requirements for neutral salt fog, humidity and "Cass" corrosion tests.

The vulcanized, rubber-lined cabinet is of double wall construction to provide uniform temperature within the test area. All saturation and heating processes are under positive control. Relative humidities of 95 to 100% from ambient temperatures to 125° are routine.

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industrial news

Joint Automatic Control Conference

Theory and application of automatic control to be featured at four-day joint meeting at Cambridge, Mass., September 6-9.

KRESGE AUDITORIUM IN Cambridge, Mass., (MIT) will be the scene of the 1960 Joint Automatic Control Conference, jointly sponsored by ASME, A.I.Ch.E., AIEE, ISA, IRE. This year's host society is ASME. (None of the participating societies will hold any other national conferences on control this year, except as part of their national meetings). An outline of the program follows:

Wednesday, September 7

- Optimal Switching
- Chemical Process Dynamics
- New Techniques in Control System Theory
- Dynamic Testing of Components and Systems
- General Papers (2 sessions)

Thursday, September 8

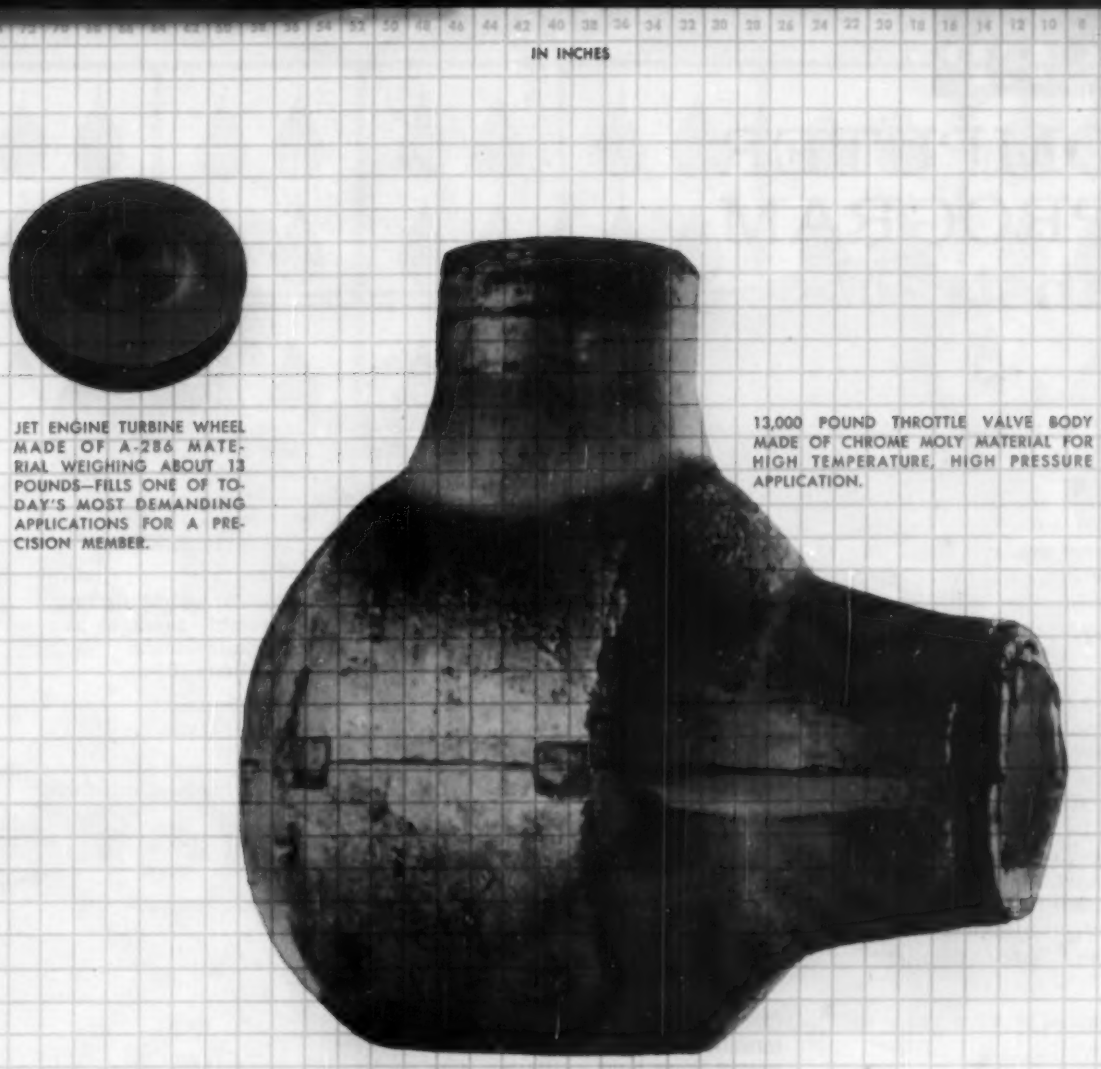
- Adaptive Control
- Selected Papers on Automatic Control
- Control Components (2 sessions)
- Synthesis and Programming of Digital Computer Control Systems
- General Papers (1 session)
- Report on First IFAC Congresss, Moscow, USSR, June 27-July 2, 1960

Friday, September 9

- Special Topics
- Case Histories and Computers for On-Line Control Systems
- Panel Discusson—Automatic Control Education
- Nonlinear Systems
- Optimum Control of Chemical Processes

A carbon black manufacturing plant now under construction in Durgapur, India, will be owned by Phillips Carbon Black, Ltd. The 22 million pounds a year capacity plant will use the Phillips Petroleum furnace black process, with coal tar distillates as feed stock. Phillips Petroleum and Duncan Bros., Calcutta, each own 30 percent of the company stock. The remaining 40 percent was subscribed by private investors.

For more information, circle No. 76 ➤



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COMPUTER PROGRAM abstracts

The Machine Computation Committee of the A.I.Ch.E. is interested in receiving program abstracts for publication as part of its program interchange activity. Details of this activity are given in the *Guide to Abstracts and Manuals for Computer Program Interchange*, which has just been revised based on experience during the first year the interchange has been functioning. Copies of the new *Guide* are available at no cost from the A.I.Ch.E. in New York.

Once again the Committee wishes to emphasize the three rules for participation in the interchange program:

1) Abstracts submitted for publication must follow the form shown in the *Guide*.

2) The submitter of the abstract agrees to make available for publication a program manual, prepared as described in the *Guide*, should sufficient interest develop.

3) Abstracts for publication, and all questions concerning published abstracts, must be sent to the Machine Computation Committee c/o A.I.Ch.E.

Two manuals are now available: *Line Sizing* and *Liquid-Liquid Heat Exchanger Design*. The latter is described July p. 161. Scheduled for completion before the end of the year are manuals on *Multicomponent Distillation (Abstract 020), Nonlinear Estimation (016), Piping Flexibility (002), and Plate-to-Plate Distillation Procedure (017).*

Polynominal equation fitting (033).

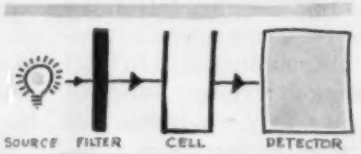
W. L. Dieckmann
Mathematical Services Group
California Research Corporation
Richmond, California

Description: This program computes the coefficients of a polynominal equation of the form:
$Y=C_0+C_1X+C_2X^2+C_3X^3+\ldots C_nX^n$
given a number of data points equal to $n+1$. Equations as high as the nineteenth degree can be handled. The program is not restricted to equal intervals for the data points. If desired, back-solutions for other values of X may be obtained.
Computer: Datatron 205, 4000 words storage, card input and output, and floating point unit.
Program Language: Datatron 205 Machine Code.
Running Time: Running time depends upon the degree of the polynominal equation. For a fifth degree equation (including back-solutions), about four minutes is required.
Availability: A manual will be prepared for publication if sufficient interest develops.

Calculation of Zimm Plot for determination of polymer molecular weight from light scattering data (046).

William I. Martin, John J. Killoran
Koppers Company, Inc.
Verona Research Center
Box 128, Verona, Penna.

Description: This program calculates the Zimm plot points (Hc/τvs $\sin^2 + Kc$) used in determining the molecular weight of a polymer from light scattering data obtained on a Brice-Phoenix Universal Light Scattering



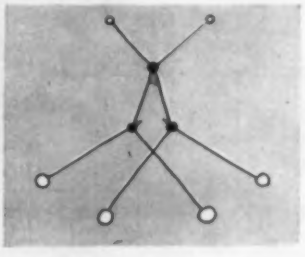
Photometer. The method is straight forward and follows formulas of Brice, Halwer and Speiser (*J. Optical Soc. of America*, 40, P. 768, 1950) which includes the modification for turbidity measurements and non-polarized light.

Computer: IBM 650 Basic.
Program Language: SOAP + SIR
Running Time: Less than three minutes to calculate points for ten angles at five concentrations.
Availability: A manual will be prepared for publication if sufficient interest develops.

Polymer molecular weight distribution from weight average and number average molecular weights of fractions (056).

Shell Chemical Company
Plastics and Resins Division
Houston, Texas

Description: This program calculates the composite molecular weight distribution according to the method of



Beall[1] from the weight average and number average molecular weight of from 1-20 separate polymer fractions. Beall's method of representing each polymer fraction by a binominal distribution is used in the program. This method of calculation takes into account both the asymmetry of distribution of the individual fractions and the overlap of molecular species contained in each fraction.
Computer: Basic IBM 650 with alphabetic attachment.
Program Language: Modified Bell Interpretive System.
Running Time: Ten minutes per fraction.
Availability: A manual will be prepared for publication if sufficient interest develops.

[1]Beall, G., *J. Polymer Sci.*, 4, 488 (1949).

continued on page 88

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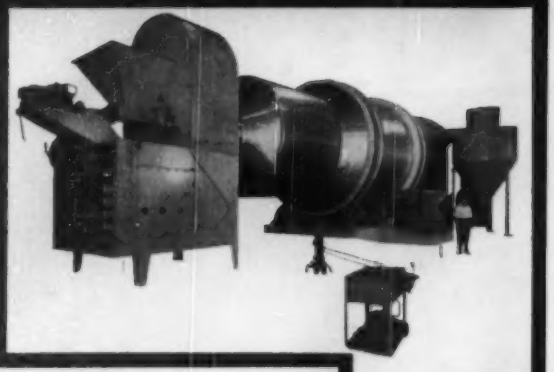

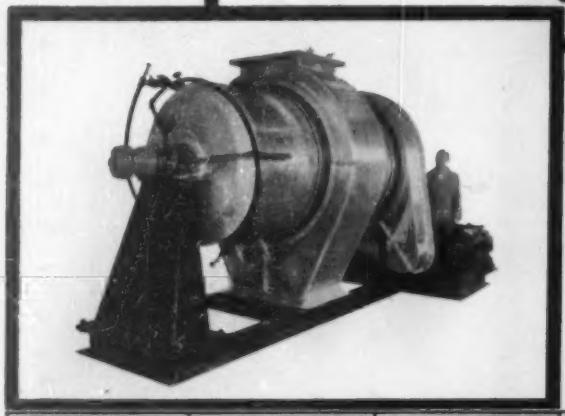

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Computer abstracts

from page 86

Machine Computation Committee

A.I.Ch.E.
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New York 36, New York

I am interested in computer program manuals corresponding to the following abstracts:

- ☐ **Polynominal equation fitting (033)**
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Centrifuges, pressure (p. 9). Info from Baker-Perkins on the HS W Universal Pressure Centrifugal — operation at 1,000 times gravity, internal pressures to 150 lb./sq. in. **Circle 84.**

Columns, extraction (p. 101). Bulletin T-1159 from General American Transportation gives full details of its RDC column. **Circle 82.**

Comparators (p. 118). Handbook from W. A. Taylor discusses theory and applications of pH control. **Circle 35.**

Computer, engineering (p. 87). The IBM 1620 prints out complete description of its optimum solution. Technical info from IBM. **Circle 94.**

Condensers (p. 94). Bulletin 129 from Niagara Blower gives description, capacities of the "Aero" vapor condenser. **Circle 32.**

continued on page 90

MATERIALS

Acetonitrile (p. 23). Detailed info from Union Carbide Chemicals on acetonitrile as an extractive distillation solvent. **Circle 77.**

Alloy, casting (p. 105). Technical info from Duraloy on "HOM," special high-nickel alloy for high-temperature castings. **Circle 46.**

Carbon, activated (p. 11). Design Guide Booklet gives basic design data for planning both liquid and vapor phase continuous column adsorptive systems. Pittsburgh Chemical Co. **Circle 93.**

Chlorine (p. 19-20). New 28-page Booklet from U.S. Industrial Chemicals gives chemical and physical properties of chlorine, shipping and handling data. **Circle 93-4.**

Defoamers, silicone (p. 92). Samples and new manual on foam control from Dow Corning. **Circle 78.**

Dimethylhydrazine, unsymmetrical (p. 19-20). Info from U.S. Industrial Chemicals on new joint venture with Food Machinery and Chemical for production of rocket fuels. **Circle 93-2.**

Gases, compressed (p. 30). Catalog from the Matheson Co., Inc., gives full technical data and prices on 85 compressed gases. **Circle 85-1.**

Gases, compressed (p. 30). The Matheson Co., Inc., offers Wall Chart "Safe Handling of Compressed Gases." **Circle 85-3.**

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SERVICES

Design and Construction, olefin plants (p. 31). Info from M. W. Kellogg on design, engineering, construction facilities. **Circle 16.**

Design and Construction, process plants (p. IBC). Brochure 97/17 from Ralph M. Parsons. **Circle 48.**

Fabrication, process equipment (p. 4). Bulletins HE and CI from Downingtown Iron Works describe design and fabrication of chemical process equipment. **Circle 98.**

Fabrication, process equipment (p. 88). Info from Edw. Renneburg & Sons on kilns, calciners, mixers, conveyors, other process equipment. **Circle 87.**

Fabrication, process equipment (p. 102). Info from Goslin-Birmingham Mfg. on evaporators, vacuum-rotary and drum dryers, filters, other process equipment. **Circle 80.**

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CEP'S DATA SERVICE—Subject guide to advertised products and services

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 89*

Condenser, tower-type (p. 77). Info from Croll-Reynolds on the "Convactor." **Circle 37.**

Conductivity Cells (p. 8). Catalog from Industrial Instruments, Inc. gives body material, physical range, conductivity range, electrode materials. **Circle 3.**

Connections, pressure-vessel (p. 106). Info on special bolt flanges, cylinder extensions, reinforcing nozzles in 96-page Catalog from Lenape Hydraulic Pressing & Forging. **Circle 100.**

Controls, pressure (p. 25). Technical info from Mercoid on 316 stainless Bourdon-tube pressure controls. Bulletin 019. **Circle 10.**

Control Systems, visual (p. 110). Booklet BE-30 from Graphic Systems. **Circle 31.**

Conveyors, pneumatic (p. 84). Bulletin 143-B from Spencer Turbine gives diagrams of typical systems, illustrative applications. **Circle 25.**

Corrosion Test Cabinets (p. 83). For environmental simulation and accelerated corrosion tests. Technical data from Industrial Filter & Pump Mfg. **Circle 6.**

Crushers, jaw (p. 112). Eight models from 2 by 6 in. to 12 by 26 in. jaw opening. Bulletin 062 from Sturtevant Mill. **Circle 40-1.**

Crushers, rotary fine (p. 112). Capacities to 30 ton/hour. Bulletin 063 from Sturtevant Mill. **Circle 40-2.**

Cylinder Valve Outlets (p. 30). Bulletin from the Matheson Co., Inc. **Circle 85-2.**

Detector, voids (p. 22). Technical data and Bulletin from Tinker & Rasor describes the M-1 TR Holiday Detector for finding voids in protective coatings. **Circle 21.**

Dryers, batch-type (p. 82). Complete Specification Bulletin from Despatch Oven Co. **Circle 26.**

Dryers, flash (p. 18). One operation in single compact unit. Bulletin 82 from Combustion Engineering, Raymond Div. **Circle 12-1.**

Dryers, fluidized-bed (p. 18). Complete technical info in Bulletin 88 from Combustion Engineering, Raymond Div. **Circle 12-2.**

Dryers, pan-type (p. 118). Bulletin 351 from Bethlehem Foundry & Machine. **Circle 56.**

Extruders (p. 119). Technical data from Davis-Standard on design of precision extrusion equipment. **Circle 97.**

Filters, leaf-type (p. 104). Filtration Data Sheet from Buffalo Filters. **Circle 23.**

Filters, vacuum (p. 26). High throughput, sharp separation, big volume. Info from Bird Machine. **Circle 54.**

Forgings, ferrous (p. 85). Complete technical info from Cameron Iron Works. **Circle 76.**

Gas Generator (p. 109). For reducing, nitrogen, carbon dioxide, hydrogen, inert, and annealing atmospheres. Info from Gas Atmospheres, Inc. **Circle 63.**

Grinding Mill, fluid-energy (p. 28). Info from Fluid Energy Processing & Equipment on the "Jet-O-Mizer" mill. **Circle 20.**

Heat Exchangers (p. 113). For wide range of temperatures and pressures, in all metals and alloys. Catalog from Engineers and Fabricators. **Circle 2.**

Heat Exchangers (p. 125). Western Supply, Heat Exchanger Div., offers Booklet on "Engineering Specialties: A Challenge." **Circle 96.**

Heat Exchangers, air-cooled (p. 10). From simple water coolers to complicated process coolers and condensers. Technical info from Smithco Engineering. **Circle 81.**

Heat Exchangers, graphite, tube and shell (p. 29). Complete info from Falls Industries. Also 32-page Booklet "Data for Cost Estimation." **Circle 55.**

Heat Exchangers, plate-type (p. 7). Seven different types in total of 20 sizes. Technical info from Chester-Jensen. **Circle 49.**

Instruments, pneumatic & electronic (p. 78-79). Bulletin 13-18 from Foxboro gives complete story. **Circle 14.**

Mills, cage (p. 117). For reduction of wet, sticky or gummy materials, as well as standard materials. Info from Stedman Foundry and Machine. **Circle 88.**

Mills, hammer (p. 112). Bulletin 084 from Sturtevant Mill describes four swing-sledge mills, four hinged-hammer pulverizers. **Circle 40-4.**

Mixers (p. 91). Complete data on paddle and turbine types in Catalog A-19 from Philadelphia Gear Corp. **Circle 106.**

Mixers (p. 108). Technical data from Gabb Special Products on new Model RL "Shear-Flow" portable mixer. **Circle 62.**

Mixers (p. OBC). Technical info on mixing problems from Mixing Equipment Co. **Circle 39.**

Mixers, portable (p. 97). Ratings 1/20 to 3 hp. Bulletin 530 from Eastern Industries. **Circle 34-1.**

Mixers, side-entering (p. 97). Sizes ¼ to 30 hp. Bulletin 620 from Eastern Industries. **Circle 34-2.**

Mixers, top-entering (p. 97). Sizes ¼ to 10 hp. Bulletin 620 from Eastern Industries. **Circle 34-3.**

Mixers, turbine (p. 97). Range of ¼ to 40 hp. Bulletin 1210 from Eastern Industries. **Circle 34-4.**

Nozzles, spray (p. 6). Catalog 24 from Spraying Systems (48-page) gives reference data on thousands of nozzle designs and materials. **Circle 18.**

Nozzles, spray (p. 96). Complete Catalog from Monarch Mfg. Works. **Circle 60.**

Nozzles, spray (p. 114). Catalog 5900 from Binks Mfg. gives applications, sizes, capacities, spray patterns, metals, selection tables. **Circle 38.**

Packings, Pall Ring and Intalox saddles (p. 36). Packed tower performance info from U. S. Stoneware. **Circle 108.**

Piping, polyethylene (p. 24). Sizes ½ to 2 in., long coils. Bulletin CE-57 from American Hard Rubber. **Circle 11-1.**

Piping, rigid PVC (p. 24). Schedules 40, 80, 120, sizes ½ to 4 in. Threaded or socket-weld fittings. Valves ½ to 2 in. Bulletin CE-56 from American Hard Rubber. **Circle 11-2.**

Piping, Teflon-lined (p. 14). Complete systems for corrosive service. Technical info from Resistoflex. **Circle 42.**

Pulverizers (p. 32). Bulletin 51A from Pulverizing Machinery Div., Metals Disintegrating, gives details of the "Mikro-Pulverizer," info on models and capacities. **Circle 33.**

Pumps, canned (p. 81). Pressures to 5,000 lb/sq. in., temperatures to 1,000°F, capacities to 600 gal./min. Composite Bulletin 1100 from Chempump. **Circle 24.**

continued on page 92

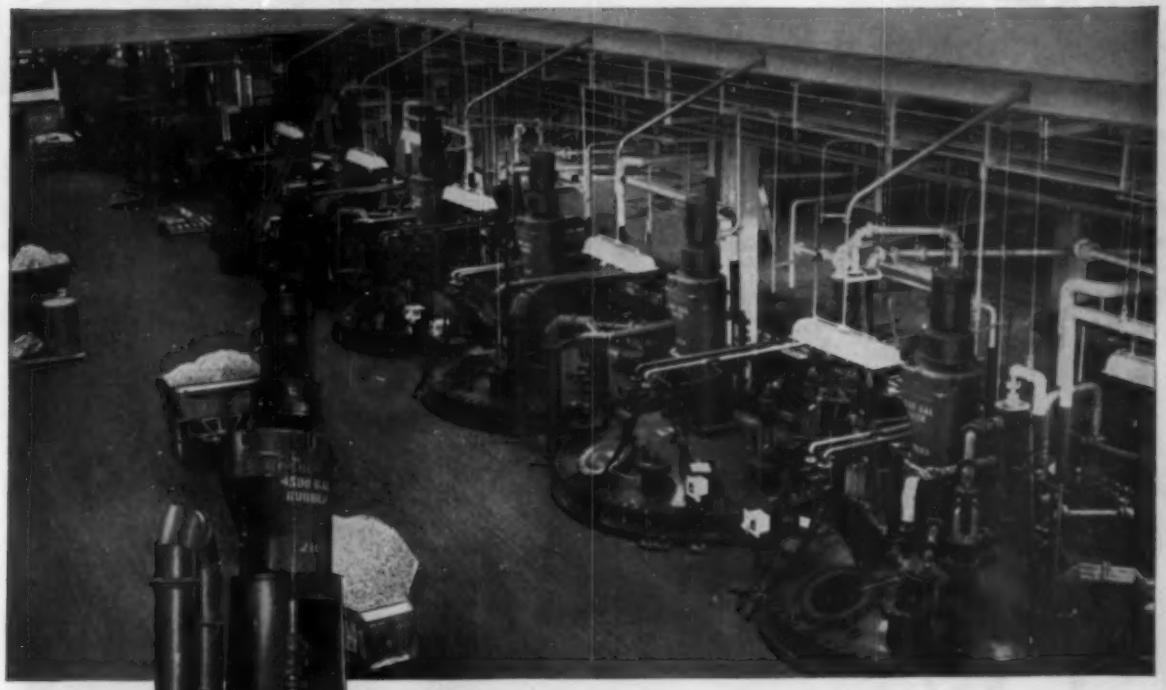
MATERIALS *from page 89*

Packing, synthetic rubber (p. 93). Specific data on heat and fluid resistance of Viton synthetic rubber available from du Pont, Elastomer Chemicals Dept. **Circle 53.**

Polyethylene (p. 19-20). Data from U.S. Industrial Chemicals on use for insulators in nuclear weapons work. **Circle 93-3.**

Sodium (p. 19-20). Technical Data Bulletin "Desulfurization of Benzene, Toluene, and Xylene by Sodium" from U.S. Industrial Chemicals. **Circle 93-1.**

YOU GET-MORE...WHEN IT'S A PHILADELPHIA MIXER!



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CEP'S DATA SERVICE—

Subject guide to advertised products and services

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 90*

Pumps, centrifugal, vertical shaft (p. 115). Sizes 1 to 8 in., capacities to 1,800 gal./min., heads to 100 ft. Pump Selector from Nagle Pumps. **Circle 9.**

Pumps, gear, rubber-lined (p. 24). All wetted parts of acid-and wear-resistant hard rubber. Bulletin CE-55 from American Hard Rubber. **Circle 11-3.**

Pumps, rotary gear (p. 117). New Bulletin G-1 from Schutte and Koerting gives full details on standard models. **Circle 29.**

Pumps, screw-type (p. 107). Bulletin 206 from Warren Pumps on external gear and bearing screw pumps. **Circle 57.**

Pumps, sulfuric acid (p. IFC). Technical data from Duriron on "Durcopumps" with wet-end parts of Durimet-20, specially designed to handle sulfuric acid solutions. Bulletin P-4-100. **Circle 45.**

Pyrometers (p. 116). Bulletin 2146 C from Illinois Testing Laboratories gives details of the "Alnor" pyrometer. **Circle 4.**

Regulators, pressure (p. 117). Full details in Bulletin C-95 from Fisher Governor. **Circle 15.**

Rolls, crushing (p. 112). Eight sizes, rates to 87 ton/hour. Bulletin 065 from Sturtevant Mill. **Circle 40-3.**

Rotameters, armored (p. 103). Bulletin 19A from Schutte and Koerting has full details of SK Metal-Tube (Armored) Rotameters. **Circle 83.**

Rupture Discs (p. 115). Sizes from 1 to 24 in., rupture pressures from 4 to 850 lb./sq. in. gauge at 72°F. Complete Catalog from Fike Metal Products. **Circle 59.**

Screeners (p. 110). Technical data from Simon-Carter Co. on rotary-motion machines of several different designs. **Circle 17.**

Separators, entrainment (p. 97). Latest design guides in knitted wire entrainment separators in Bulletin ME-9 from Metal Textile. **Circle 86.**

Sifters (p. 5). For single or multiple separations down to 325 mesh. Bulletin 503 from B. F. Gump describes the "Bar-Nun" sifter. **Circle 79.**

Sulfur Burners (p. 112). Bulletin 100 from Chemipulp Process Inc. describes the Chemipulp KC jet-type sulfur burner. **Circle 5.**

Tanks, rubber-lined (p. 109). For safe storage of most corrosive liquids. Info from Gates Rubber Co. Sales Div. **Circle 61.**

Tanks, wood, polymer-lined (p. 116). For handling and storage of chemical solutions. Bulletins from Wendnagel. **Circle 30.**

Telemetering Systems (p. 95). Bulletin from Vapor Recovery Systems describes new pulse-code power gauge system. **Circle 47.**

Valves (p. 119). Info from George W. Dahl on Series 4000 valves, six body types in ⅛ to ½ in. NPT sizes. **Circle 1.**

Valves, chemical (p. 24). Plastic or rubber-lined. ⅛ in. pet cocks to 24 in. gate valves. Info from American Hard Rubber. **Circle 11-4.**

Valves, control (p. 34). Complete technical info from Annin. **Circle 36.**

Valves, control, large (p. 27). Bulletin CV-53 from Kieley & Mueller gives details of Standard globe-type valves in 20, 24, 30, and 36 in. sizes, larger on special order. **Circle 44.**

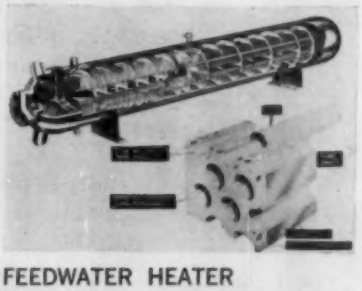
Valves, gate, jacketed (p. 114). Catalog J-50 from Hetherington & Berner gives details of new model with replaceable seats. **Circle 43.**

Valves, porcelain (p. 21). Catalog 567 from Lapp Insulator has complete info on chemical porcelain. **Circle 95 .**

Vessels, transport (p. 97). Wheeled vessel for handling liquids and semi-solids in batches from 50 to 150 gallons. Info from Hubbert. **Circle 58.**

Water Treating Equipment (p. 117). Complete plants for demineralization, dealkalizing, clarification, silica, iron, and manganese removal, water softening. Catalog from Hungerford & Terry. **Circle 28.**

DEVELOPMENT OF THE MONTH



FEEDWATER HEATER

(Circle 602 on Data Post Card)

The new feedwater heater (shown above) from Westinghouse Electric Corp. features a hemispherical inlet chamber and a new type of joint between tubes and tube sheet.

The improved joint was developed in construction of nuclear steam generators. The tubes are welded to a clad tube sheet that has a layer of nickel followed by additional layers of nickel-copper alloys welded on its surface (see photo above).

continued on page 94

SEALING AGAINST SOLVENTS, CRUDE OIL, CRESOL, GASOLINE...

VITON® PACKINGS UNHARMED BY 2 YEARS' FLUID EXPOSURE

With the reputation that VITON synthetic rubber has built for heat resistance (serviceable at 450° F. and up), engineers sometimes overlook the value of its outstanding performance in contact with fuels, oils, solvents and chemicals. Here is an application* where fluid resistance was the *only* problem ... and VITON the only answer.

In 1957, General American Transportation Corporation installed a new fluid loading system at its tank farm in Galena Park, Texas. Swivel joints on the system required packings made of rubber. The problem: what rubber could handle crude oil, solvents, gasolines, cresol and sodium cresylate—to mention just a few of the fluids in storage? The answer: Du Pont VITON.

For well over two years, packings made of VITON, Du Pont's new fluoroelastomer, have been used in General American's tank car loading system to handle more than 80 different fluids. A recent visual inspection revealed no swelling, no deterioration and not a trace of product leakage. What's more, every packing originally installed (72 in all) is still in service.

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Outstanding resistance to oils, fuels, solvents and chemicals, as well as to elevated temperatures, has helped VITON improve performance of refinery valves, heat exchangers, pumps and a wide range of industrial equipment. Write for specific data on the heat and fluid resistance of this new elastomer. E. I. du Pont de Nemours & Co. (Inc.), Elastomer Chemicals Department CEP-8, Wilmington 98, Delaware.

*This case history from the ELASTOMERS NOTEBOOK—subscription free on request.

PROPERTIES OF VITON

Hardness Range	60-95 Shore A
Tensile Strength	Over 2,000 psi.
Temperature Range	—40° F. to 600° F.
Chemical Resistance	Excellent
Oil Resistance	Excellent
Compression Set Resistance	Very Good
Ozone Resistance	Outstanding
Flame Resistance	Good
Sunlight and Weather Resistance	Very Good
Abrasion Resistance	Good

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NEOPRENE HYPALON® VITON® ADIPRENE®

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holds temperatures to close limits in entire processing column

● This Niagara "Aero" Vapor Condenser produces constant temperatures, assures sustained capacity to this fractionating column, holding production and quality uniform. A closed system, it avoids fouling troubles, holds temperatures within specified limits at all points.

It gives a higher vacuum than conventional type condensers, effectively separating the non-condensibles at the condensate outlet, with sub-cooling after separation.

It produces this higher vacuum with use of less steam and power. It holds its full capacity with only a nominal consumption of water, using air as the cooling medium. It answers the question of water supply or disposal.

Mounted directly on the steel structure of the evaporator or distillation column, installation is simple, operation is dependable, maintenance is neither troublesome or expensive. For description and capacities write for Bulletin 129.

NIAGARA BLOWER COMPANY

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District Engineers in Principal Cities

For more information, Circle No. 32

SUBJECT GUIDE to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT

301 Blowers, heavy-duty. Information describing advanced design of the new lobe-type rotary positive blowers and gas pumps from Sutorbilt Corp.

302 Compressor, centrifugal. A 20-page Bulletin from Clark Bros. Co. introduces packaged air compressors for air separation plants.

303 Computer. A 36-page Reference Manual presents detailed information for the general purpose digital computer pb 250 from Packard Bell Computer.

304 Computer, refinery design. Report from Royal McBee Corp. describes how the LGP-30 handles complex material balances in plant design.

305 Controller, temperature. Information from Alnor Instrument Co. describes new, electronic on-off controller and pyrometric temperature indicator.

306 Equipment. The 1960-61 General Catalog covering equipment for the process industries from General American Transportation Corp.

307 Equipment, dry processing. Booklet covers complete line of dry processing equipment from Sturtevant Mill Co.

308 Equipment, meters, feeders, controls. A Bulletin from B-I-F Industries, Inc. provides capsule info about available products and systems.

309 Equipment, process. Bulletin 200-B describes complete line of process equipment and systems from Sprout, Waldron & Co., Inc.

310 Equipment, process. Latest inventory list of process equipment from Perry Equip. Corp.

311 Equipment, processing. Bulletin from Selas Corp. of America lists units for removing solids, liquids, or vapors from fluid systems.

312 Exhaust System, plastic. Brochure describing exhaust systems made of PVC, polyethylene, polypropylene from Industrial Plastic Fabricators, Inc.

314 Fans, centrifugal. New 60-page Bulletin from American-Standard describes series of centrifugal-type airfoil bladed fans.

315 Feeders. New Bulletin from Fuller Co. describes roll and vane-type feeders and rotary valves.

316 Flow Meter. Details from Fischer & Porter Co. describes miniature flow meter designed for measuring low flow rates of liquids or gases.

317 Fluid Meters, compensation. Literature from Bailey Meter Co. describes electric and pneumatic systems which

continued on page 96

MATERIALS

349 Alkyd Resins. A 50-page Treatise entitled "The Story of Alkyd Resins" from the Brighton Corp. discusses processing and equipment.

350 Calcium Carbide. New 16-page Brochure from National Carbide Co. features versatility of calcium carbide and its derivative, acetylene.

351 Carbide Alloys. New 24-page Booklet from Kennametal Inc. illustrates over 75 uses of hard carbide alloys.

352 Cement, heat transfer. Bulletin 600 from Thermon Mfg. Co. describes heat transfer cement for electric resistance heaters.

354 Ceramic Fibers. Data Sheet from The Carborundum Co. describes and gives applications for a castable form of ceramic fiber.

355 Chemicals. A 36-page Catalog lists all chemical products available from Food Machinery and Chemical Corp.

356 Chlorendic Acid. New 12-page Bulletin gives specs, properties, reactions for "HET" acid for paints, coatings, etc. from Hooker Chemical Corp.

357 Corrosion Inhibitor. Corrosion control in cooling water systems using inhibitor compound from Calgon Co. is subject of new Bulletin.

continued on page 98

SERVICES

366 Computer Mathematics. New 16-page Technical Report details mathematical applications of DYSTAC computer from Computer Systems, Inc.

367 Engineering Services. New 12-page Brochure describes service of Dorr-Oliver Inc. in development of a variety of plants on a world wide basis.

368 Infrared Radiation. An 8-page Technical Bulletin from Fostoria Corp. discusses infrared source theories and laws, radiation theory, color blindness, etc.

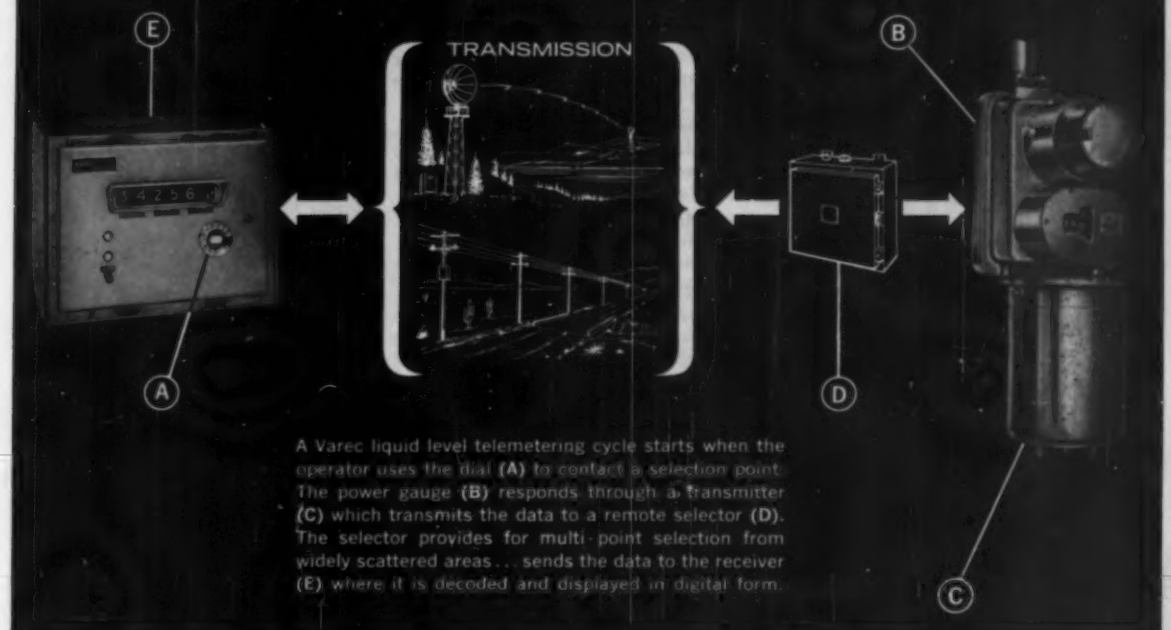
369 Ion Exchange. A 7-page Technical Reprint from Nalco Chemical Co. discusses recent developments in water treatment processes.

371 Thermocouples, reference table. Standard reference tables for thermocouples are available with the comliments of the West Instrument Corp.

372 Water Treatment. A 6-page Technical Reprint from Nalco Chemical Co. considers scale, corrosion, microbiological growth in cooling water treatment.

VAREC PULSE CODE POWER GAUGE SYSTEM

ACCURACY-TO 1/16 INCH OR BETTER IN GAUGING AND TELEMETERING LIQUID LEVEL DATA



A Varec liquid level telemetering cycle starts when the operator uses the dial **(A)** to contact a selection point. The power gauge **(B)** responds through a transmitter **(C)** which transmits the data to a remote selector **(D)**. The selector provides for multi-point selection from widely scattered areas... sends the data to the receiver **(E)** where it is decoded and displayed in digital form.

Varec combines its new DYNAMATIC* 8400 Series Power Driven Tank Gauge with the Varec Pulse Code to provide an accurate, reliable liquid level measurement/telemetering system. The new system transmits data 'error-proof' over a single communications channel... gives a reading accurate to 1/16 inch in just 5 seconds.

Varec's pulse code method of dots and dashes supplies a fast reading with a slow pulse rate of 5 pulses per second so the transmission channel is not critical. Wiring costs are reduced with a single transmission circuit between the remote selector and receiver. (For smaller installations, a direct-wired system can be used instead of selectors.)

Standard receivers are available in capacities of 10, 100, or 1000 point selection.

ONLY THE **VAREC** SYSTEM OFFERS ALL THESE ADVANTAGES:

ACCURACY: Provides 1/16 in. gauging accuracy with new Power Driven Tank Gauge... transmits 'error-proof' reading by pulse code.

RELIABILITY: Consists of simple, compact electro-mechanical components... needs no vacuum tubes or other complex electronic equipment.

FLEXIBILITY: Designed on a building block principle that permits unlimited variety of system arrangements such as telemetering other measurements... or adding remote control, data logging and alarm systems.

ECONOMY: Requires just a simple transmission circuit... a metallic pair or a carrier derived channel operated over existing lines or microwave. Costs little more than conventional systems.

EXPERIENCE: This highly accurate, reliable liquid level measurement/telemetering system offered by Varec, pioneers in the gauging field... over six years experience in pulse code applications.

For complete information, write for Bulletin CP 3707, Dept. CEP-1224-1.

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Are your scrubbing nozzles as efficient as you think they could be? Do they resist corrosion or wear conditions satisfactorily — produce the breakup and distribution you would like?

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NOZZLES FOR:

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- HUMIDIFYING
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Write for Catalog I

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For more information, Circle No. 60

CEP'S DATA SERVICE—

Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 94*

compensate pressure and temperature variations.

318 Heaters, immersion. Data from Dean Products, Inc. describes the double-embossed Panelcoil for immersion heating or cooling.

323 Mass Spectrometer. Bulletin describing new 21-130 medium-priced mass spectrometer from Consolidated Electrodynamics Corp.

324 Pipeline Spacers. Data sheets with features, specs, installation tips for pipeline insulating spacers from Plico Div. of Moon Mfg. Co.

325 Pressure Controls. Bulletin from The Mercoid Corp. describes general purpose, weather-proof, explosion proof 316 stainless steel Bourdon tubes.

326 Pumps, aluminum alloy. Information and flow curves available for aluminum alloy centrifugal pumps from J. C. Carter Co.

327 Pumps, ductile iron. Bulletin from Peerless Pump describes complete line of single and multi-stage horizontal pumps cast in ductile iron.

329 Pyrometer, optical. New 6-page data Sheet describes complete line of pyrometers from Leeds & Northrup Co.

330. Recuperator. Booklet discussing theory of recuperator fintubular heat transfer from Brown Thermal Products Corp.

332 Relief Valves. Information for integral relief valves for Warren screw or gear pumps from Warren Pumps, Inc.

333 Sampler, automatic. Catalog describes operating mechanism of machine for taking samples from continuous, wet or dry stream of material. Hardinge Co., Inc.

334 Separators. The 1960 Separator Catalog from Southwestern Eng. Co. shows applications of vibro-energy separator.

336 Thermocouple, accessories. A new 32-page Catalog lists complete line of thermocouple fittings, pressure sealing glands, and accessories from Conax Corp.

337 Thermocouple Components. New 28-page Catalog contains specifications for thermocouple assemblies from Minneapolis-Honeywell Regulator Co.

338 Tubes, gas transport and storage. Bulletin containing capacities and dimensions of gas handling tubes from Harrisburg Steel Co. and Taylor-Wharton Co.

339 Tubing. Twelve-page Catalog describes capabilities of Uniform Tubes, Inc. in making fine tubing from alloys, ferrous and non-ferrous metals.

342 Valves, aluminum armored. Details from Lapp Insulator Co. describes aluminum armored porcelain valves.

343 Valves, control. A 40-page specification Catalog from Hoffman-Odom Co. covers air control valves.

344 Valves, control. Brochure from OPW-Jordan describes sliding gate diaphragm control valves.

345 Valves, corrosion resisting. Bulletin from Duriron Co., Inc. presents data for top and bottom lubricated plug valves.

346 Valves, cylinder. A 16-page Catalog describes complete line of cylinder valves from The Bastian-Blessing Co.

347 Viscosimeter, electrical rotation. Details from Brinkmann Instruments, Inc. cover applications for new viscosimeter for measuring viscosity of process streams.

MATERIALS *from page 94*

358 Lithium. Technical Data Sheet presents chemistry of lithium and contains literature available from Foote Mineral Co.

359 Packing. A packing Selection Chart helps select proper packing for specific industrial proceses. Raybesto-Manhattan, Inc.

360 Plastic Coating. Data from Pfaudler Co. describes development of Penton spray coating technique.

361 Plastics, molded laminated. Technical Data on molded Formica laminated plastics available from Formica Corp.

362 Polyalkylene Glycol. New 52-page Booklet presents new data, properties, uses of polyalkylene glycol fluids and lubricants. Union Carbide Chemical Co.

364 Urethane Foams, mineral extenders. An 8-page Technical Report from Minerals & Chemicals Corp. of America discusses reduced costs and changed properties through use of inert mineral extender.

365 Wax. A 16-page Brochure contains specifications for microcrystalline wax and resume of the Bareco Wax Co.

A.I.Ch.E. Membership

Brochure—"Know Your Institute"—tells objective aim and benefits to chemical engineers who join this nation-wide organization, includes membership blank. Circle number 600 on Data Post Card.

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Candidates for A.I.Ch.E. Offices

Here are the brief biographical sketches and records of accomplishment of the candidates for the 1960 A.I.Ch.E. national elections. Candidates have been chosen by the Nominating Committee (members listed on the next page) unless otherwise designated as nominated by petition. Space does not permit the presentation of full details of these men's careers, and additional details of their education and career are available on request from the Secretary's Office. Further nominations by petition may be accepted until October 3, and any received will be announced with brief biographical data in the next available issue of CEP. Ballots will be mailed from the Secretary's Office in October.

. . . *nominated as officers for 1961*

PRESIDENT

J. J. HEALY—Industrial Executive. Member of the Corporate Planning Group, Monsanto Chemical Co. ('58-); Merrimac Chem. Co. ('21-'29); Monsanto Chemical Co. ('29-). Asst. to vice-pres. Research, Devel. & Engineering ('51-'56), Dir. of Development of Rsch. and Engineering Division ('56-'57), Monsanto Chemical Co. In his present position on Monsanto's Corporate Planning Group, he is responsible to the president for all phases of long range planning for the company. **A.I.Ch.E.:** Dir. ('48-'50) and ('57-); chmn. ('48-'50) Local Sections Committee; Institute Representative on Engineering Manpower Commission ('54-'57); Nominating Committee ('57-'58); Constitution & By-Laws Committee ('56-); Admissions Committee ('44-'49); active in local sections, was chmn. ('35) Boston Section.

TREASURER

J. HENRY RUSHTON — Educator, Consultant, Past-President ('57) and Treasurer ('58-) of A.I.Ch.E., Prof. chem. eng. ('55-) Purdue. Consultant, Dept. of Defense, A.E.C. firms in petrol. & food indust.; tech. advisor, Mixing Equip. Co.; Prof. & dept. head ('37-'46), U. of Va.; prof. & dir. of dept. ('46-'55), Ill. Inst. Tech. Author: mixing scale-up, low-temp. operations, others. A.I.Ch.E.: President ('57), vice-pres. ('56), Dir. ('52-'54); chmn. Local Sect. Activ. Comm.; has been chmn. Student Chapters, Projects, Future of Inst. Comms. Chicago Sect. dir. ('52-'55). Walker Award ('52). Mbr. A.S.E.E. (past mbr. Council, secy. ad hoc Comm. on Eval. Engrg. Educ.); Engineers Council for Professional Development (mbr. Educ. & Accred. Comm.); N. Y. Chemists' Club (past non-res. v.p.).

SECRETARY

F. J. VAN ANTWERPEN — Secretary and Executive Secretary of A.I.Ch.E. ('55-). Publisher and bus. mgr. ('55-) A.I.Ch.E.; editor of CEP ('47-'55). **A.I.Ch.E.:** Founder of New Jersey Section; Awards Comm. ('47-); Hist. of the Institute Comm. ('53-'55); secy., 50th Anniv. Comm. ('55-'58); Admissions Comm.; Finance Comm. ('55-); Nuclear Energy Comm. ('52-'57); Program Comm. ('47-); Publications Comm. ('47-); Public Relations Comm. ('44-'55), chmn. ('44-'47); Standard System of Symbols and Nomenclature Comm. ('47); EJC Committee of Secretaries; Member-Giving Committee for the UEC; AEC Advisory Committee on Industrial Information; member ASEE ('56); EJC-Atomic Energy Panel ('55-'56); American Documentation Inst. ('55-'57); Who's Who in Engineering; Co-author of History of the Institute. Author of technical articles.

VICE-PRESIDENT

JOHN J. McKETTA* — Educator, Consultant, Publisher, Executive. Grad. prof. & chmn. ChE, Univ. of Texas ('46-); Bd. of Trust. & chmn. Acad. Comm., Tri-State Coll. ('58-); Advis. Bd., Eng. Found., Univ. of Texas ('57-); Advis. Bd., J. Chem. Ed.; Chmn. Edit. Bd., Pet. Ref. ('54-); Bd. Dir. Gulf Pub. Co. ('53-); Advis. Bd. Chem. Eng. Prog. ('57-'58); Advis. Bd. Interscience Pub. ('57-); Pres. Chemoil Consultants, Inc. ('58-); Member Bd. of Dir. of 5 companies. Author 75 tech. articles, 3 books. **A.I.Ch.E.:** Council ('58-); Chmn. Membership Comm. ('54-'58); Chmn. Contrib. Comm. ('60); Vice-chmn. Ad Hoc Comm. ('59-'60); Symbols & Nomenclature Comm. ('56-); Accred. & Inspect. Comm. ('56-); Nominating Comm. ('58); A.I.Ch.E. rep. on ECPD Prof. Comm. ('59-). Active South Texas Section, chmn. ('54).* **Also nominated by petition.**

W. R. MARSHALL, JR. — Educator, Consultant. Assoc. Dean, College of Engineering, Univ. of Wisconsin, and Assoc. Director, Engineering Exp. Station, Univ. of Wisconsin. E. I. du Pont ('41-'47); Assoc. Prof. ChE. ('47-'53) Univ. of Wisconsin; Professor and Assoc. Dean ('53-), Univ. of Wisconsin. Consultant to industry in drying, atomization, heat and mass transfer, and related topics. Co-author of text illustrating applications of differential equations to chemical engineering problems; author of Drying section in Perry's Chemical Engineering Handbook; author or co-author of over 30 technical papers. **A.I.Ch.E.:** Dir. ('56-'58); served on Equip. Testing Procedures Comm., Program Comm., Standards Comm., and Awards Comm.; best presentation award at 1950 Annual Mtg.; Institute Lecturer ('52); Walker Award ('53); Professional Progress Award ('59).

DONALD F. OTHMER* — Educator, Consultant. Professor and head Department of Chemical Engineering, Polytechnic Institute, Brooklyn, N. Y. Consulting engineer to many U. S. and foreign companies; to United Nations; to U. S. Army (Chem. Corps, Ord. Corps), Navy, Dept of Interior, Dept. of State, foreign government agencies. Author or co-author of over 200 articles, many patents on unit operations, process design, application of thermodynamics & kinetics, etc. Co-editor 17-vol. Encycl. Chem. Tech.; Advis. Bd. Perry's Chem. Eng. Handbook; editor Fluidization, co-author Fluidization and Fluid Particle Systems. **A.I.Ch.E.:** Director ('56-'58); chmn. New York Sect. ('44); chmn. Tech. Prog. Comm., N.Y. meeting ('48); member many other committees; director E.J.C. ('57-'58); 1958 Stephen L. Tyler Award, New York Section, A.I.Ch.E.* **Nominated by petition.**

. . . . nominated as directors for three-year terms beginning 1961

THEODORE A. BURTIS — Industrial Executive. President, Houdry Process Corp. ('56-); Chemical engineer, Magnolia Petroleum Co. ('43-'45); Sales engineer, Owens-Corning Fiberglas Co. ('46-'47); Section head ('47-'52), director of development ('52), chief process engineer ('52-'55), associate manager, Research & Development Division Houdry Process Corp. ('55-'56). Author of various technical papers, patents in petroleum refining. **A.I.Ch.E.:** Public Relations Comm. ('48-'50), chmn. ('58-'59); Admissions Comm. ('56-), vice-chmn. ('60); ECPD Comm. on Recognition ('58-'59); Comm. on Institute Services ('59). Philadelphia-Wilmington Section ('48-'56), director, secretary, public relations chmn., program comm. chmn., Engineering & Technical Societies Council, PR chmn. Atlantic City Meeting ('51).

JOHN W. CLEGG—Industrial Executive. Manager, Chemical Engineering Department, Battelle Memorial Institute ('53-); Research engineer, du Pont ('41-'44); Research engineer ('44-'47), asst. chief ('47-'49), chief ('49-'53), Chemical Engineering Division, Battelle Memorial Institute; Lecturer, Ohio State University ('50). Author of many technical articles and patents, one book. Registered Professional Engineer (Ohio). **A.I.Ch.E.:** Chmn. Central Ohio Section ('52); Technical program chmn., Columbus, Ohio, Meeting ('50); Program Committee ('50-'51, '58-'59); Program Committee, Nuclear Science Congress ('58); Chmn. Nuclear Engineering Division ('59); Dynamic Objectives Committee ('60).

HAROLD G. DONNELLY* — Educator. Professor and head, Department of Chemical and Metallurgical Engineering, Wayne State Univ., Detroit, Mich. Instr., Chem. Eng., Wayne State Univ. ('36-'37); Asst. dir. of res., Compressed Industrial Gases, Inc., ('37-'38); Instr., Chem. Eng. ('38-'42), asst. professor ('42-'46), assoc. professor ('46-'51), professor ('52-). Registered professional engineer (Mich.). Consultant to many industrial companies. Author of technical papers. **A.I.Ch.E.:** Junior Activities Comm. ('46-'47); Professional Guidance Comm. ('46-'51), chmn. ('51-'53); Comm. on Economic and Professional Status ('48); Local Sect. Comm. ('49-'51); National rep. to ECPD Comm. on Professional Training ('53-'58). Detroit Section, sec.-treas. ('46-'47), vice-chmn. ('48), interim chmn. ('49). ***Nominated by petition.**

GERALD L. FARRAR*— Technical Editor, Educator, Industrial Engineer. Engineering Editor ('52-), Oil and Gas Journal, Tulsa, Oklahoma. Assistant professor of chemical engineering ('47-'50), associate professor of chemical engineering ('50-'52), Agricultural and Mechanical College of Texas; Chemical engineer and engineering supervisor ('43-'47), Magnolia Petroleum Company and Socony-Vacuum Oil Company. Licensed professional engineer (Texas). Has written more than fifty technical articles, holds patents. **A.I.Ch.E.:** Active in Institute affairs since 1942. Vice-chairman ('58), chairman ('59), Tulsa Section; assistant general chairman, Tulsa Meeting ('60); Public Relations Committee ('55-'57); Sections Activities Committee ('59); Nominating Committee ('60). ***Nominated by petition.**

RAPHAEL KATZEN— Consultant. Pres. Raphael Katzen Associates International, Inc. ('53-); Chem. eng. ('36), Cellutate, Inc.; Dir. res. ('37-'40). Northwood Chemical; Northwood res. fellow ('40-'42). Polytechnic Inst. of Brooklyn; Tech. super. ('42-44) Diamond Alkali; Proj. eng. ('44-'50), asst. man. ('50-'52), man. ('52-'53), Vulcan Eng. Div. **A.I.Ch.E.:** Charter member, Cleveland & Ohio Valley Sect.; Treas., vice-chmn., chmn., Ohio Valley Sect. ('49-'52); Tech. prog. co-chmn., Cincinnati Meeting ('58); Distillation symp. chmn., Mexico City Meeting ('60); **A.I.Ch.E.** rep. U.S. Commission for UNESCO ('55); Local Sect. Comm. ('51-'54); Prof. Dev. Comm. ('53-'56); Prog. Comm. ('57-'59); Career Guidance Comm. ('53-'59), vice-chmn. ('56), chmn. ('57-'59); Stand. Comm. ('56-), chmn. Subcomm. on Distillation Tower Stand. ('59-).

ROBERT J. McNALLY— Industrial Executive. Vice-president, Garfield Chemical and Manufacturing Corp. ('60-). Manager ('59-'60), sales manager ('57-'59), Garfield Chemical and Manufacturing Corp.; Assistant manager ('51-'57), Sulfuric Acid and Liquid Sulfur Dioxide Department, American Smelting and Refining Co.; Superintendent ('47-'51), assistant superintendent ('45-'47), production supervisor ('36-'45), General Chemical Division, Allied Chemical Corp. **A.I.Ch.E.:** First chairman ('55-'56), Great Salt Lake Section; Member of Executive Committee for four years; General chairman, National Meeting, Salt Lake City ('58).

MAX S. PETERS—Educator. Prof. & head of Div. of Chem. Eng., Univ. of Ill. Chem. eng., plant operations ('42-'44) Hercules Powder Co.; ('44-'46) U. S. Army; Tech. plant super. ('47-'49) G. I. Treyz Chem. Co.; Fellow ('49-'51) Penn State Univ.; Asst. prof. ('51), prof. ('57-), head of Chem. Eng. ('58-), Univ. of Ill.; Lic. Prof. Eng. Author numerous tech. articles on reaction kinetics and design, and two textbooks, George Westinghouse Award, ASEE, ('59). **A.I.Ch.E.:** Chmn. ('60), vice-chmn. ('59), Central Ill. Section; Prog. Comm. ('58-); Prof. Dev. Comm. ('56-); Reaction Kinetics Area Comm. ('59-); Student Chap. Advisor ('57-'60); Chmn., Plant Design Sect., Educ. Films Comm. ('54-'56); Chmn., Reaction Kinetics Symp. ('54), Washington, D.C. Meeting; Tech. Prog. Comm. ('60), Mexico City Meeting.

CARL F. PRUTTON—Industrial Executive, Educator. Executive vice-president, Chemical Divisions, Food Machinery and Chemical Instructor ('20-'25), assistant professor ('25-'29), associate professor ('29-'35), professor and head of Chemical Engineering Department ('36-'48), Case Institute. Chief, Process Development Branch, Office of Rubber Director ('42-'44); Consultant ('28-'41) Dow Chemical; Consultant ('29-'51) Lubrizol Corp; Director of research ('48-'49), vice-pres. ('49-'53), Mathieson Chemical; vice-pres. & technical director ('54-'56) Chemical Divisions, FMC. Over 100 patents for lubricants and chemical processes. Author of numerous technical papers. **A.I.Ch.E.:** Chmn. of Cleveland National Meeting; Former chmn. Cleveland Local Section.

CHARLES W. SWARTOUT—Industrial Executive. Operations Manager, Mallinckrodt Chemical Works ('55-). Development engineer, Linde Air Products Co. ('37-'42); 2nd Lt. to Major, Manhattan District, U. S. Army Corps of Engineers. Army operations officer, Wilmington Area ('42-'44), chemical construction officer, electromagnetic, Y-12 Area, Oak Ridge, Tenn. ('44-'45), assistant production officer, Y-12 Area ('45-'46); Chief eng. Mallinckrodt Chemical Works ('46-'55). Inventor or co-inventor of six patents relating to flame drilling of rock and processes for mold coatings. **A.I.Ch.E.:** General chairman, 46th Annual Meeting, St. Louis ('53); Campaign co-ordinator (St. Louis Sect.) United Engineering Center ('58); Nominating Comm. ('59); Chmn. Public Relations Comm. ('60).

ROBERT R. WHITE— Educator. Director, Institute of Science and Technology, & professor of chemical engineering, Univ. of Mich. Instr., Chem. Eng. ('42-'43), Univ. of Mich., asst. professor ('43-'46), assoc. professor ('46-'48), professor ('48-'58), assoc. dean, College of Engineering (half-time) & assoc. dean, Horace H. Rackham School of Graduate Studies (half-time) ('58), director, Institute of Science and Technology & professor of chemical engineering ('59). Registered prof. eng. (Mich.) Consultant to many industrial companies. Author or co-author of more than sixty technical articles. **A.I.ChE.:** Junior Award ('45); Presentation Award ('51); Professional Progress Award ('56); Dynamics Objectives Comm.; Pub. Bd., A.I.Ch.E.J.; Program Comm. (reaction kinetics); vice-chmn. Accreditation Comm.

MEMBERS OF THE NOMINATING COMMITTEE

D. L. Katz, chairman
E. B. Christiansen
D. A. Dahlstrom
G. L. Farrar
W. B. Franklin
J. G. Knudsen
J. L. Olsen

meeting preview

R. L. Rorschach
Warren Petroleum Co.
Tulsa, Oklahoma

Tulsa—Oil capital of the nation

Tulsa, Oklahoma, the country's leading oil center, plays host to A.I.Ch.E. National Meeting September 25-28. Here is a last minute report on special meeting events, what to see, and where to go.

An enjoyable as well as technically informative A.I.Ch.E. National Meeting is coming up this fall, reports indicate. Committee members have gone all out in plans to show their city to attendees. Visitors to Tulsa, Oklahoma, site of the gathering September 25-28, will find, contrary to the popular image, a city of trees, hills and lakes. Tulsa has grown by leaps and bounds in a short time to its present status as the oil capital of the country, and the control center for a large share of petroleum operations in the Western Hemisphere and Middle East. In addition, it is one of five major industrial areas in the southwest, and the manufacturing center of Oklahoma.

This is a far cry from a city which was not incorporated until 1896, although Tulsa's known history dates back to 1836. Then, Archie Yahola, a Creek Indian, settled there and presided over the community council, one of the town groups in the Creek national government. While the first white settlement was in 1882, it was not until the discovery of oil nearby in 1901, that things began to boom in Tulsa. Since 1920, the population has grown from 75,000 to today's 255,000, with 339,000 in the county area.

Major oil center

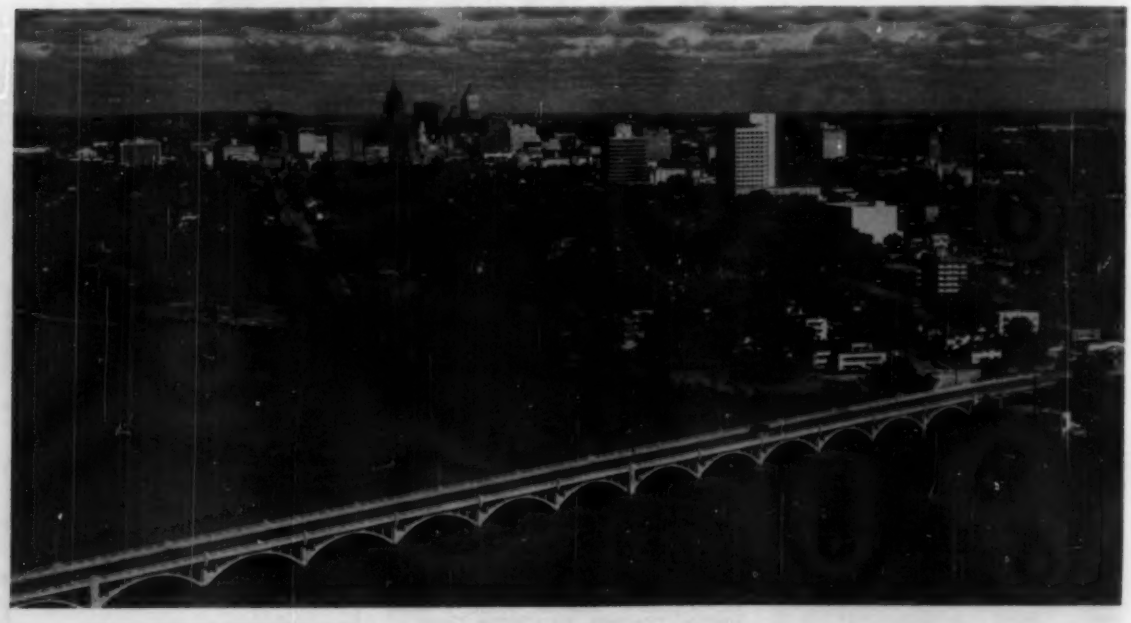
Tulsa now has more than 20,000 people working in plants and offices of 500 oil firms, exclusive of oil equipment manufacturing and supply firms. Besides fabricating industries, there are refineries, fertilizer, cement and other chemical processing plants. The city has five major petroleum laboratories and the outstanding School of Petroleum Science at the University of Tulsa. A research and education center for the area, it also holds the national headquarters of several leading professional and petroleum operations associations.

Barbecued buffalo

The special events, Ladies' Program and Plant Tours arranged as part of the National Meeting are calculated to give a birds' eye view of this thriving city. Highlight of the special events agenda is an outing to Woolaroc Ranch and Museum. The Ranch, located 45 miles from Tulsa on the tribal lands of the Osage Indians, will host an exhibition of Indian and Western dances, and an outdoor meal with barbecued buffalo the main course. A tour of the ranch grounds and the Museum is in order.

Feature of the Ladies Program is a visit to the four-acre Tulsa Rose garden. The garden contains over

continued on page 102



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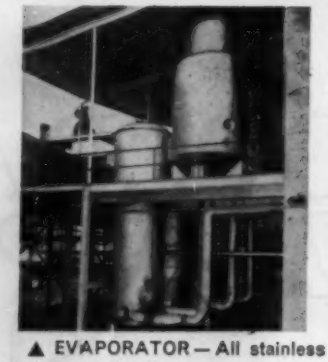

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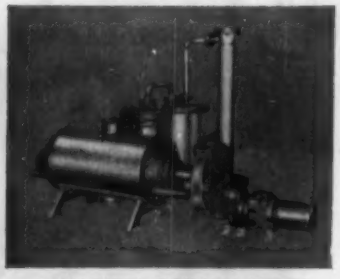

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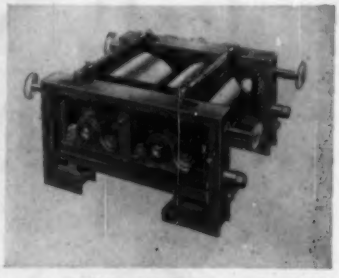

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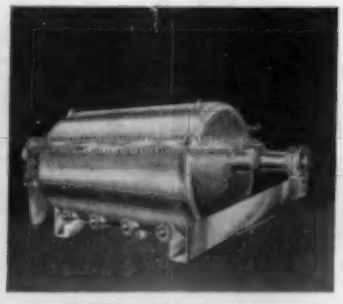

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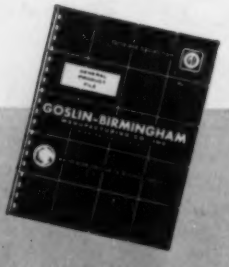

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Tulsa

from page 100

9000 rose plants, and one of the dozen rose testing gardens in the United States. The Garden Center, located in the $80,000 mansion of an early oil king, houses a library, lecture hall and meeting place. The nine-gallery Philbrook Art Center, also on the ladies' list, has, in addition to its permanent display, a monthly visiting art collection.

The Thomas Gilcrease Institute of American History and Art is considered to have one of the world's most important collections of American history and art, with particular emphasis on the American Indian. It was presented to the city of Tulsa in 1955 by Thomas Gilcrease, a local citizen of Creek ancestry.

Plant tours take in some of the leading area industry. On the list are: American Airlines Maintenance Depot, huge jet center, first in the airline industry which was planned expressly for jet age overhaul.

Grand River Chemical Co.: Produces anhydrous ammonia, agricultural and feed grade urea and urea-ammonia solutions.

DX Sunray Oil Co.: This refinery, one of the largest lube oil manufacturing facilities west of the Mississippi, produces 75,000 bbls. of crude a day at capacity.

Texaco Refinery: principally manufactures motor fuel. Capacity, 39,000 bbls. a day. Also open for viewing will be National Tank Co.'s plant, Jersey Production Research Laboratory and Public Service Co. Power plant.

High spot of the four day meeting is the traditional dinner-dance. Dr. Kenneth McFarland, educational consultant and lecturer for General Motors is the featured speaker. He has been noted as one of the nation's outstanding speakers by the National Chamber of Commerce, so a special treat is in store. #

A 30 million pound phthalic anhydride plant planned by Witco will use a naphthalene-oxidation process. Slated for completion in late 1961 on a site not yet chosen, the plant will be on the east coast.

Acetic acid, acetic anhydride and methyl ethyl ketone are among 400 chemicals to be made at Union Carbide Chemicals new Brownsville, Texas, plant. The company's third unit of this type in Texas, it is expected to begin operations in about one year.

A.I.Ch.E Candidates

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions. These names are listed in accordance with Article III, Section 8 of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members and Associate Members will receive careful consideration if received before July 15, 1960, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

MEMBER

Aaron, Henry O., *Wilmington, Del.*
Aaronson, Irving, *La Puente, Calif.*
Alexander, Robert L., *ElDorado, Ark.*
Ashley, Jay H., *Midland, Mich.*

Biles, William R., *Pasadena, Texas*
Brewer, Jerome, *Allentown, Pa.*

Chirgwin, L. D., Jr., *Stamford, Conn.*
Christensen, Edward R., *Beacon, N. Y.*

DiMaggio, Anthony J., *Pottstown, Pa.*
Dungan, Theodore A., *San Francisco, Calif.*

Elkin, Harold F., *Philadelphia, Pa.*
Elston, James W., *Baltimore, Md.*
Epstein, Norman, *Vancouver, B.C., Canada*

Gitterman, Henry, *Teaneck, N. J.*
Green, Robert M., *Foxboro, Mass.*

Hastert, Robert C., *Cleveland, Ohio*
Hirasawa, Paul S., *Idaho Falls, Idaho*

Jackson, Jefferson M., Jr., *Lake Charles, La.*
Jurevic, William G., *Columbus, Ohio*

Knap, James E., *Charleston, W. Va.*
Kuehl, Rollo H., *Auburn, Mich.*

Lawson, Donald W., *Texas City, Texas*
Leem, Mark E., *Crossett, Ark.*
Lewis, David M., *Schenectady, N. Y.*
Lloyd, Robert, *W. Mifflin, Pa.*

Margolin, Stanley V., *Auburndale, Mass.*
Mecca, William E., *Newark, Del.*
Moore, James D., *Salt Lake City, Utah*
Morrow, Wallace E., *Akron, Ohio*

Penick, Joe E., *Augusta, Kans.*
Phinney, Donald C., *La Canada, Calif.*
Pierce, Robert R., *Natrona Heights, Pa.*

Robinson, D. B., *Edmonton, Alta., Canada*

Sampson, Jack, *Lake Jackson, Texas*
Silva, Alfonso F., *Oklahoma City, Okla.*
Sloan, Arthur Wm., *Alexandria, Va.*
Soparkar, Ramesh G., *Calcutta, India*

Vasan, Srini, *New York, N. Y.*

Wahrmund, Robert C., *Baytown, Texas*
Wherry, Thomas C., *Bartlesville, Okla.*
Wright, Robert G., *New Orleans, La.*

ASSOCIATE MEMBER

Ableson, Arthur E., *Grants, N. M.*
Ablon, Jerome, *New York, N. Y.*
Abrams, David S., *Silver Spring, Md.*
Adams, Hubert L., *Nevada, Mo.*
Adamson, David S., *El Segundo, Calif.*
Aid, Joe R., *Wilmington, Del.*
Aitken, Gordon, *Watkins Glen, N. Y.*
Albert, Michael B., *Penn Valley, Pa.*
Aldrich, Robert Hart, *Rowayton, Conn.*
Alford, Peter B., *Rochester, N. Y.*
Allard, Peter F., *Havertown, Pa.*
Allen, Phillip R., *Stratford, Conn.*
Allen, Robert F., *Rochester, N. Y.*
Allison, Charles E., Jr., *Tarentum, Pa.*
Anderson, Erwin M., Jr., *Grand Rapids, Mich.*
Anderson, Malcolm R., *Madison, Wisc.*
Anderson, Richard F., *Painesville, Ohio*
Anderson, Robert W., *Salt Lake City, Utah*
Anderson, Virgil L., *Williamsport, Ohio*
Ando, Hiei, *New York, N. Y.*
Angelosante, Talentino, *Allen Park, Mich.*
Anthony, Russell D., Jr., *Houston, Texas*
Armstrong, Carl D., *Cape Girardeau, Mo.*
Armstrong, Melton G., *Port Arthur, Texas*
Avant, Thomas G., *Auburn, Ala.*

Bacher, Joseph, *Bronx, N. Y.*
Baerg, William, *Stanford, Calif.*
Baker, Herman J., Jr., *Hopewell, Va.*
Baker, John E., *Port Arthur, Texas*
Barnard, R. D., *Harvey, Ill.*
Barone, Vito S., *Saginaw, Mich.*
Barrios, Cyril, *Slidell, La.*
Bateman, Roger S., *Albany, Ore.*
Baublits, John E., *Hanover, Pa.*
Bayer, Frederick F., Jr., *Scarsdale, N. Y.*

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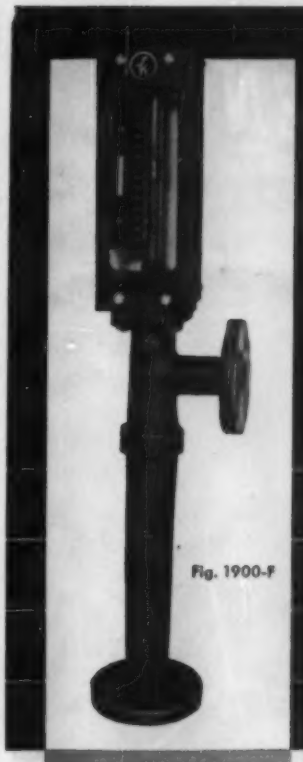

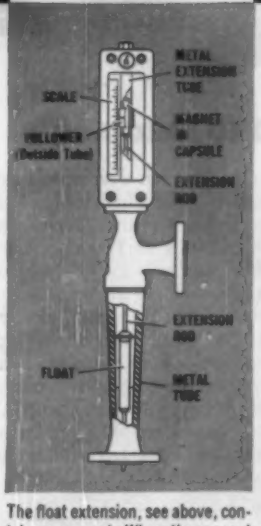

The float extension, see above, contains a magnet. When the magnet moves in the extension tube, the follower (outside the extension tube) follows. The follower position, in relation to the meter scale, indicates rate of flow.

SK Metal-Tube (Armored) Rotameters were specially designed for measuring the rate of flow of hazardous fluids, fluids under high pressures, and steam in chemical, petroleum, and other industrial plants.

These SK Rotameters combine accuracy with sound design and sturdy construction to provide an easy-to-apply, easy-to-use instrument of considerable versatility. For, the Metal-Tube Rotameter can be used for direct reading or it can be arranged for remote indicating, recording, or controlling of fluid rate-of-flow.

This instrument is made for tough service—has a tapered metal tube with flanged connections as shown, metal extension tube, float with magnetic extension, magnetic follower, meter scale, and a sturdy "Safeguard Type" indicator case.

Get complete details. Write to SK for new Bulletin 19A.

QUICK DELIVERY FROM STOCK

For Immediate Delivery, Standard SK Jet Ejectors, Rotameters, and Flow Indicators are stocked in Cornwells Heights (Phila.), Pa., Houston, Texas, and San Francisco, Calif.

Schutte and Koerting COMPANY
INSTRUMENT DIVISION
2245 STATE ROAD, CORNWELLS HEIGHTS, BUCKS COUNTY, PA.

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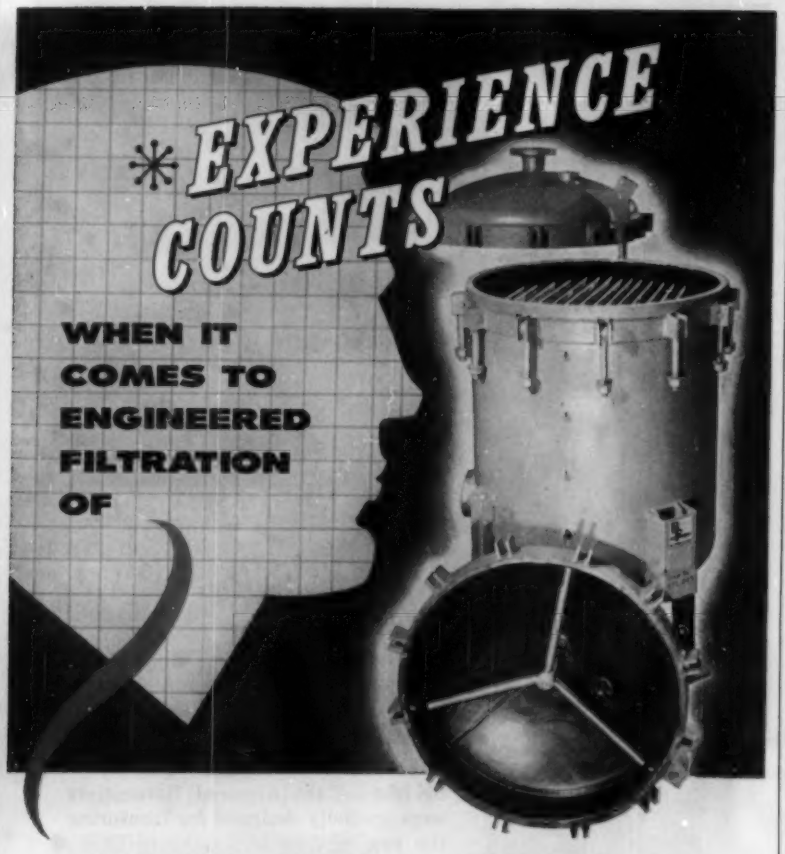

• HOT MINERAL ACIDS • ORGANIC ACIDS

The experience of our engineers over a long span of time has developed many highly productive, highly successful and highly profitable leaf filter designs constructed with a variety of materials to handle hydrochloric, sulfuric, fumaric and other mineral or organic acids. These feature tank linings of Hypalon, butyl rubber, plastisol and vinyl coatings to name a few materials currently being used for these strong acids. Leaf designs include materials of zirconium, titanium, polypropylene and PVC which have been proven for these services. Quick/Change polypropylene bags are common to most installations of this type and facilitate installation on leaf frames without operator sewing. Style of installation gives full security and tight surfaces which improve sluicing cake discharge economy. Additional features such as the efficient Rotary-Sluice, Reslurry Air Ring, Filtrate "Policeman" protective assemblies and Spacers are produced in this same variety of materials. Basic Vertical and Horizontal Tank Leaf Filters are available in these materials and are much less expensive than you may think.

You are invited to use this experience to virtually eliminate corrosion problems and improve your filtering operation. Our staff and sales agents are ready to help you. Why not drop us a line, now!

If you have a hot acid problem, write for our confidential filtration data sheet or phone Victoria 5455.

BUFFALO FILTERS, INC.
1807 ELMWOOD AVE. BUFFALO 7, N. Y.

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Candidates

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Bayliss, Ronald W., *Freeport, Pa.*
Bazaire, Keith E., *Wilmington, Del.*
Bea, Donald A., *Washougal, Wash.*
Beaudoin, Jean Marc, *Duluth, Minn.*
Bednowitz, Allan L., *Brooklyn, N. Y.*
Bellefleur, Gilles N., *Arvida, Que., Canada*
Bennett, Harold L., *St. Clair, Mo.*
Berardi, Lloyd F., *Rochester, N. Y.*
Bergman, Howard G., *Ft. Belvoir, Va.*
Bergonzoni, Aldo, *Westfield, N. J.*
Bergstad, Ralph, *Corvallis, Ore.*
Bertinot, Benjamin E., *McIntosh, Ala.*
Bidrawn, John, *Ames, Iowa*
Bidstrup, Wayne W., *Fairport, N. Y.*
Birr, Harold E., *Mendon, Mich.*
Bishop, Jerrold K., *New York, N. Y.*
Black, Myron, *Brooklyn, N. Y.*
Blackford, Alfred F., *Somerville, N. J.*
Blacksburg, Alvin Brent, *Somerville, N. J.*
Blair, Robert J., *Lancaster, S. C.*
Blakeney, William R., *Hartsville, S. C.*
Bodde, Bernard P., *Vermilion, Ohio*
Bode, M. C., *Bristol, Pa.*
Bohl, Thomas Lee, *Bozeman, Montana*
Bomben, John L., *Concord, Calif.*
Bonnet, Juan A., *Rio Piedras, Puerto Rico*
Boschwitz, Stewart Carl, *Bronx, N. Y.*
Boyd, Charles W., *Burkburnett, Texas*
Braden, William B., Jr., *Waco, Texas*
Bradshaw, Jerry, *Center, Texas*
Brandoni, William R., *Cleveland, Ohio*
Brandt, Donald C., *Liverpool, N. Y.*
Briccs, Gerald J., *San Francisco, Calif.*
Briggs, William C., *Muskogee, Okla.*
Brinkley, Donald R., *La Grange, Mo.*
Brinson, Robert James, *W. Lafayette, Ind.*
Brochu, Ronald L., *Springfield, Mass.*
Brooks, Carl E., Jr., *Newark, Ohio*
Brooks, Edward C., *Tia Juana, Venezuela, S. A.*
Brooks, Kenneth W., *Tulsa, Okla.*
Brown, Jerome R., *No. Augusta, S. C.*
Brown, Paul Wayne, *Columbus, Ohio*
Brubaker, William James, *Watkins Glen, N. Y.*
Bruger, Louis, *Ladysmith, Wisc.*
Bublitz, Donald W., *Essexville, Mich.*
Buffington, Marlyn K., *Forest City, Iowa*
Burnett, Ronald D., *Houston, Texas*
Burns, Allen N., *Houston, Texas*
Butler, Thomas B., *Texas City, Texas*
Byington, Joseph A., *Wilmington, Del.*

Camp, Joseph S., *Ardmore, Pa.*
Campbell, J. David, *Irwin, Pa.*
Carstens, Ronald A., *Ponca City, Okla.*
Caswell, Walter R., *Wakefield, R. I.*
Cekada, Joseph, Jr., *Cleveland, Ohio*
Chapel, Dan G., *Howell, Mich.*
Chludzinski, George, *Brooklyn, N. Y.*
Churchill, G. William, *Tell City, Ind.*
Chute, Robert W., *Columbus, Ohio*
Cirrito, Vincent, *Brooklyn, N. Y.*
Clancy, Robert J., *Detroit, Mich.*
Clark, Lewis W., *Stamford, Conn.*
Clasing, Henry K., Jr., *Teaneck, N. J.*
Clay, Don R., *Washington C. H., Ohio*
Clearwater, William R., *Clifton, N. J.*
Cline, C. Douglas, *Rutherford College, N. C.*
Coates, Alfred E., *Wakefield, R. I.*
Collins, Braxton W., *Spartanburg, S. C.*
Collins, Melvin A., *Midland, Mich.*
Colvin, H. R., *Lake Jackson, Texas*
Comeaux, Ray James, *Port Arthur, Texas*
Compton, Henry W., *Summit, N. J.*
Condy, Harvey A., *Montreal, Que., Canada*
Cook, Michael, *New York, N. Y.*
Cooper, Roger L., *St. Louis, Mo.*
Corcoran, Edward M., *Kew Gardens, N. Y.*
Corvese, Donald J., *Kingston, R. I.*
Cosgares, Andrew, Jr., *Norman, Okla.*
Cossette, Marcel, *Montreal, Que., Canada*
Costa, Kenneth, *Kingston, R. I.*
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Crossley, Guy A., *Cincinnati, Ohio*
Crowe, Hollis E., *Orno, Me.*
Curtis, David, *Cleveland, Ohio*
Cushing, Gerald W., *Paliende, Nebr.*
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Dalton, Bill N., *Lawrenceville, Ill.*
Danek, Frank C., *Cleveland, Ohio*
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Day, Frederic F., *Port Arthur, Texas*
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Dean, James C., Jr., *Livingston, Texas*
Deeds, David C., *Amherst, Ohio*
DeGraff, Charles D., *No. Canton, Ohio*
Deibert, Max C., *Belmont, Mass.*
DeJean, Ronald, *Baton Rouge, La.*
DeMarkey, William, Jr., *Greenwich, Conn.*
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Devors, Donald F., *Clearwater, S. C.*
Dewey, Richard C., *Cincinnati, Ohio*
Dietz, Russell N., *Wantagh, N. Y.*
Diliello, Luke M., *Baltimore, Md.*
Ditzel, James P., *Batavia, N. Y.*
Dixon, Harold W., *La Marque, Texas*
Dixon, Leon A., *Hazleton, Pa.*
Donaldson, John Wm., *Indianapolis, Ind.*
Dougherty, G. N., Jr., *Easton, Pa.*

Doyle, Francis J., *Philadelphia, Pa.*
Drake, Allan L., *Interlaken, N. Y.*
Driscoll, Patrick L., *Saginaw, Mich.*
Drury, Alton G. *Scobey, Montana*
Duckworth, Gordon L., *Calgary, Alta., Canada*
Duncker, Charles P., *Brentwood, Mo.*
Dunskus, Thomas, *Cambridge, Mass.*
DuPuy, L. H., *Texas City, Texas*
Dutcher, Dennis L., *Sioux Falls, S. D.*

Earl, Thomas C., *Allentown, Pa.*
Early, Jonathan E., *Kingsport, Tenn.*
Eberhardt, Bruce A., *Mountain Lakes, N. J.*
Edwards, Jerry L., *Fayetteville, Ark.*
Edwin, Richard V., *W. Hempstead, N. Y.*
Eichenseer, Robert L. *Evanston, Ill.*
Elde, Paul H., *Cincinnati, Ohio*
Eklund, Jon A., *Ashland, Mass.*
Elgin, Arthur C., Jr., *Chevy Chase, Md.*
Ellwanger, John R., *Flushing, N. Y.*
Englert, Thomas M., *Paducah, Ky.*
Estill, Joseph O., *Lima, Ohio*
Estrada, V., *Vedado, Habana, Cuba*

Fass, Stephen, *Union, N. J.*
Fell, Robert Frank, *Copake, N. Y.*
Federico, Kenneth P., *New Orleans, La.*
Feinman, Nathan, *Port Chester, N. Y.*
Feitel, J. York, Jr., *New Orleans, La.*
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Feng, Louis T., *Highland Park, Mich.*
Fieteison, Sidney S., *Shenandoah, Pa.*
Fischer, Henry B., *E. Cleveland, Ohio*
Fishberg, Lewis D., *Trenton, N. J.*
Fisher, Robert E., *Midland, Mich.*
Fletcher, Frederick L., *Southgate, Mich.*
Flounders, Edmund M., *Allentown, Pa.*
Flury, Roy, *Lakewood, Ohio*
Folstein, Robert L., *Silver Spring, Md.*
Folsenlogen, Paul D., *Dallas, Texas*
Fontenot, D. J., *Ville Platte, La.*
Forsch, Thomas R., *Sault Ste Marie, Mich.*
Fortune, William D., *Warwick, R. I.*
Foster, Robert, *Chicago, Ill.*
Fowler, Frederick D., *Bedford, Ind.*
Fox, Chester R., *Flushing, N. Y.*
Franke, F. R., *Gainsville, Fla.*
Franke, Richard H., *Pittsburgh, Pa.*
Fraser, Malcolm Douglas, *Pittsburgh, Pa.*
Freeman, Robert M., *New York, N. Y.*
Friedly, John C., *Mounderville, W. Va.*
Fritz, Edward J., *Cleveland, Ohio*
Fuller, Ronald, *Clinchco, Va.*
Funk, George H., *Plumsteadville, Pa.*

Gainer, John Lloyd, *Pasadena, Md.*
Gallo, Anthony J., *Niagara Falls, N. Y.*
Garbarini, Charles J., Jr., *Pelham Manor, N.Y.*
Garow, Jay, *Bronx, N. Y.*
Garufi, Robert C., *Bronx, N. Y.*
Gasda, Thomas D., *Bethlehem, Pa.*
Gasaway, Charles L., *San Francisco, Calif*
Genco, Joseph Michael, *Columbus, Ohio*
Gerdes, William H., *Freehold, N. J.*
Gerstner, Richard T., *Mineola, N. Y.*
Gessner, Henry Y., *Brooklyn, N. Y.*
Gibson, Carroll J., *Borger, Texas*
Gibson, Dennis L., *LaGrange, Ill.*
Gieseke, William D., *Latrobe, Pa.*
Gill, William N., *Syracuse, N. Y.*
Givand, Theodore E., *Brooklyn, N. Y.*
Glenn, Robert W., *Valdosta, Ga.*
Glovier, Robert Ivan, *Wilmington, Del.*
Goldberg, Morris, *Brooklyn, N. Y.*
Goldstein, Jack B., *Laurelton, N. Y.*
Goral, Robert J., *Beaver Meadows, Pa.*
Gorring, Robert L., *Ann Arbor, Mich.*
Gray, John Richard, *Beaumont, Texas*
Gray, Michael H., *Spartanburg, S. C.*
Gray, Thomas, *Three Rivers, Que., Canada*
Greenstein, Bernard, *Bronx, N. Y.*
Grove, Andrew S., *Elmhurst, N. Y.*
Gruehmeyer, William, *Columbus, Ohio*
Gruenling, Edwin H., Jr., *Newark, N. J.*
Grusser, Robert Y., *Flushing, N. Y.*
Gustafson, George Robert, *Des Plaines, Ill.*
Gutierres, Carlos D., *So. Plainfield, N. J.*

Haartz, David Winsor, *Andover, Mass.*
Hackworth, John H., *Bethlehem, Pa.*
Hafner, Eugene R., *Orange, Texas*
Hall, Richard D., *Newark, Ohio*
Hallemann, Fred A., *New Haven, Mo.*
Hallman, Donald F., *Ward, S. C.*
Hamill, Thomas, *Brooklyn, N. Y.*
Hamilton, Boyd L., *Bishop, Texas*
Hamilton, Joshua Pearre, *Nashville, Tenn.*
Hampton, Richard John, *Luchine, Que., Canada*
Handiak, Nicholas, *Montreal, Que., Canada*
Hansen, John E., *Duluth, Minn.*
Haq, S. S., *Rolla, Mo.*
Hardister, Rex J., *Pine Bluff, Ark.*
Harris, Alexander T., *Highland Park, Mich.*
Hart, Clifford Leslie, *Cleveland, Ohio*
Hart, Marcus R., *Oakland, Calif.*
Hassard, Graham T., *Orange, Conn.*
Hauser, Rolland, *Ames, Iowa*
Hawk, Ralph Leroy, *Irondale, Mo.*
Haydon, Kinnett J., *Lebanon, Mo.*
Hazel, James W., *Niagara Falls, N. Y.*
Hebert, Leslie E., Jr., *St. Gabriel, La.*
Heckman, David Henry, *Pemberville, Ohio*
Helms, Andrew E., *LaMarque, Texas*
Henry, Allan L., *Grand Rapids, Mich.*

continued on page 106

HOW TO BEAT THE HEAT

for strong high alloy requirements in the 1,800° to 2,300° F range!

DURALOY HOM*

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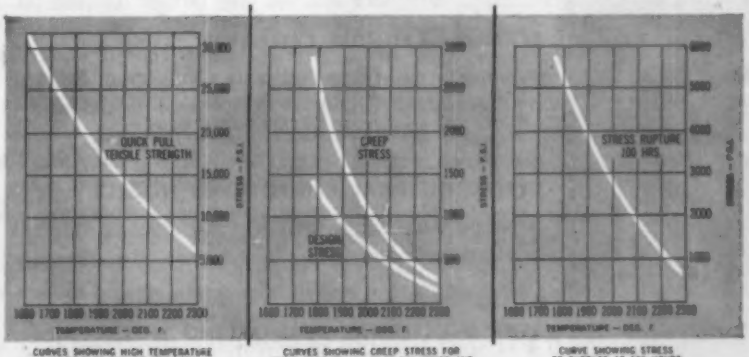
casting alloy

Duraloy "HOM" is a special high nickel alloy developed to produce castings that meet high temperature requirements, especially when castings are subject to oxidizing atmospheres.



CURVES SHOWING HIGH TEMPERATURE SHORT-TIME TENSILE STRENGTH OF DURALOY-HOM

CURVES SHOWING CREEP STRESS FOR CREEP RATE OF 1% IN 10,000 HOURS AND RECOMMENDED DESIGN STRESS FOR DURALOY-HOM

CURVE SHOWING STRESS TO RUPTURE AT 100 HOURS FOR DURALOY-HOM

Castings of DURALOY "HOM" are now being produced by our three methods: static, centrifugal and shell molded. Write today for additional information on this versatile new alloy.

The DURALOY Company
OFFICE AND PLANT: Scottdale, Pa.
EASTERN OFFICE: 12 East 41st Street, New York 17, N. Y.
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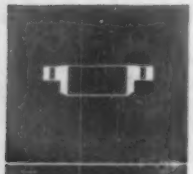
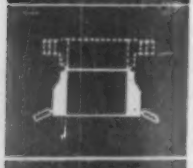
LENAPE OFFERS A NEW CONCEPT IN PRESSURE VESSEL CONNECTIONS

Now—by combining a Lenape ASA bolt flange which is a short seamless welding neck and your choice of three seamless bodies, you get optimum reinforcement, design flexibility and economy.



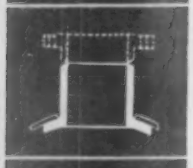
SPECIAL ASA BOLT FLANGE

Simple, low cost attachment, with easier alignment and orientation. You can choose different materials for body and flange, as well as length with unmatched economy in lengths over 12".



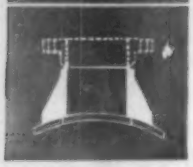
SEAMLESS CYLINDER EXTENSION

Superior to pipe or rolled plate. No seams. Built-in reinforcement. Choice of length and thickness.



TYPE C INTERNAL REINFORCING NOZZLE

Separate bolt flange makes more efficient internal reinforcement possible.



TYPE D EXTERNAL REINFORCING NOZZLE

External attachment with massive reinforcement.

All of these are available in 300 to 900 lb. ASA standards.

Full details and specifications are given in the new 96-page Lenape Catalog. Write for your copy.

LENAPE
PRESSURE VESSEL CONNECTIONS

LENAPE HYDRAULIC PRESSING & FORGING CO.
DEPT. 120 WEST CHESTER, PA.
RED MAN PRODUCTS

For more information, turn to Data Service card, Circle No. 100

Candidates

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Herbert, Victor P., *St. Louis, Mo.*
Herndon, Jerry R., *Longview, Texas*
Herring, Richard N., *Allentown, Pa.*
Hetherington, George F., *Pointe Claire, Que., Canada*
Hildreth, Nelson, *Roosevelt, N. Y.*
Hill, Anthony R., *Waban, Mass.*
Hill, Richard A., *New Brunswick, N. J.*
Hill, Ronald Hugh, *Albany, Texas*
Hillegas, William J., Jr., *Harleysville, Pa.*
Hillier, Don E., Jr., *Galveston, Texas*
Hinsch, James E., *Dearborn, Mich.*
Hirsch, Robert W., *Brooklyn, N. Y.*
Hodges, Michael E., *Panama City, Fla.*
Hocksema, Vernon L., *Muscatine, Iowa*
Hoffman, Robert P., *Pittsburgh, Pa.*
Hohenbrink, Mark F., *Ft. Jennings, Ohio*
Holz, Rudolf John, *Warren, Mich.*
Hone, Roger F., Jr., *Rahway, N. J.*
Hope, John S., *Dallas, Pa.*
Horton, Howard James, *Farrell, Pa.*
Howard, Gordon R., *Germantown, Ohio*
Howrey, Kent, *Jasper, Mo.*
Hsu, Yih-Yun, *Cleveland, Ohio*
Hudgens, Paul N., *Pensacola, Fla.*
Hundley, Preston B., Jr., *Lynchburg, Va.*
Hunsecker, William H., *Quakertown, Pa.*
Hunt, John W., *Jacksonville, Fla.*
Hymowitz, Jerome B., *Brooklyn, N. Y.*

Jackson, William C., *Philadelphia, Pa.*
Jacobs, Stanley C., *New Kensington, Pa.*
Jenkins, Richard A., *Ruston, Md.*
Johnson, Cecil J., *Dayton, Ohio*
Johnson, Paul W., *W. Hyattsville, Md.*
Johnson, Theodore O., *McKeesport, Pa.*
Johnson, William F., *Landover Hills, Md.*
Johnston, Richard, *Detroit, Mich.*
Joyner, Nelson T., Jr., *Anchorage, Ky.*
Joyner, R. W., *Ft. Worth, Texas*

Kahane, Richard A., *Eastchester, N. Y.*
Kaiser, Albert F., *Wilkes-Barre, Pa.*
Kamin, Norman P., *Boulder, Colo.*
Kanyok, James, *Parma, Ohio*
Kaplan, Gerson N., *Brooklyn, N. Y.*
Kaplan, Leonard, *Bronx, N. Y.*
Karesh, Warren G., *Bamberg, S. C.*
Kenard, Raymond J., Jr., *Los Angeles, Calif.*
Kern, Mitchell J., *Brooklyn, N. Y.*
Kilgore, Louis C., *Redondo Beach, Calif.*
Kim, Sok Taek, *Dekalb, Ill.*
King, Kenneth, *Palo Alto, Calif.*
King, Merrill K., *Pittsburgh, Pa.*
Kiscaden, D. C., *Waynesboro, Va.*
Klahn, Mona Fay, *Rochester, N. Y.*
Knapp, Gerhard, *Parkersburg, W. Va.*
Knapp, John Richard, Jr., *Monaca, Pa.*
Kohut, William, *Bethlehem, Pa.*
Koo, George P., *Seattle, Wash.*
Korchinski, Illirion J. O., *St. Louis, Mo.*
Kravitz, Lawrence R., *Dorchester, Mass.*
Kronenberg, Edward S., III, *Carlisle, Pa.*
Krudwig, Walter L., *Joplin, Mo.*
Krueger, Sheldon, *Maplewood, N. J.*
Krulik, Leon, *Parma Heights, Ohio*
Kulpinsky, Joseph C., *Yonkers, N. Y.*
Kurtz, Kenneth D., *Dover, Ohio*

Lakid, Joseph John, Jr., *W. Mifflin, Pa.*
Lambroussis, Harry G., *Houston, Texas*
Lander, Lynn Howard, *Brooklyn, N. Y.*
Langlinais, P. Lynn, *Abbeville, La.*
Lanigan, William F., *New Orleans, La.*
Lapham, Jerome, Jr., *Glens Falls, N. Y.*
LaPrad, James B., *Detroit, Mich.*
Lashover, J. H., *Arabi, La.*
Latham, Robert Roy, *Pittsburgh, Calif.*
Laughter, Ronald W., *Victoria, Texas*
Law, George D., *Midland, Mich.*
Lawhon, Richard Allen, *St. Joseph, Mo.*
Lazur, George J., *Shenandoah, Pa.*
Leclerc, James R., *Lachine, Que., Canada*
Lee, Alfred, *Montreal, Que., Canada*
Lee, Gim F., Jr., *Zanesville, Ohio*
LeFevre, Leroy, *Big Spring, Texas*
Legendre, Richard, *Fall River Mass.*
Lerner, Howard, *New York, N. Y.*
Levengood, Darvin L., *Levittown, Pa.*
Levine, Gerald M., *Duluth, Minn.*
Levy, Alan Stuart, *Brooklyn, N. Y.*
Levy, Roger, *St. Louis, Mo.*
Lew, Leong W., *San Antonio, Texas*
Lewis, Manuel J., *Brooklyn, N. Y.*
Libarkin, Morton, *Brooklyn, N. Y.*
Lichtenheld, Robert H., *Detroit, Mich.*
Lick, James S., *Allentown, Pa.*
Limbert, Frank J., *Botkins, Ohio*
Lincoln, Joseph A., *Lyons, Mich.*
Lindabery, George Peter, *Pottersville, N. J.*
Lindquist, Raymond G., *Philadelphia, Pa.*
Lindros, Donald Alan, *Santa Maria, Calif.*
Lipson, Elliot, *Jackson Heights, N. Y.*
Lisa, Irving, *Lyndhurst, N. J.*
Livingston, Owen Walker, *Cloverdale, Ala.*
Logan, Robert J., *Houston, Texas*
Long, Wesley M., *Pittsburgh, Pa.*
Lowder, Gerald R., *LaMarque, Texas*
Lucht, Gerald [illegible], *Cleveland, Ohio*

Ludwig, Allen C., *San Antonio, Texas*
Lumpkin, William B., *Coweta, Okla.*
Lunney, Samuel W., *Charleston, S. C.*
Lyche, David W., *Grand Forks, N. D.*

Macchiaroli, Nick Thomas, *McKeesport, Pa.*
Machado, Joseph John, *Bristol, R. I.*
Mack, Herman H., *LaMarque, Texas*
Mack, Lawrence Anthony, *Pittsburgh, Pa.*
Magre, Dale, *Crystal City, Mo.*
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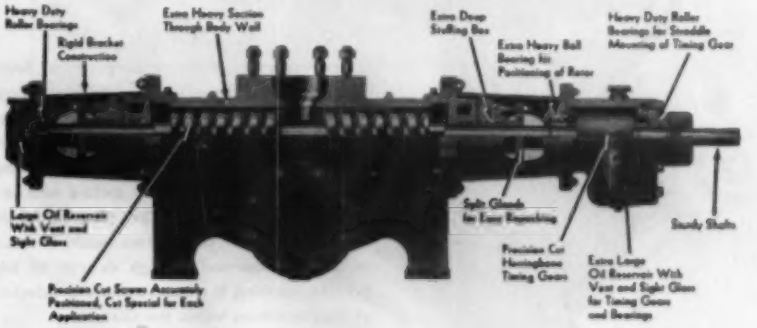
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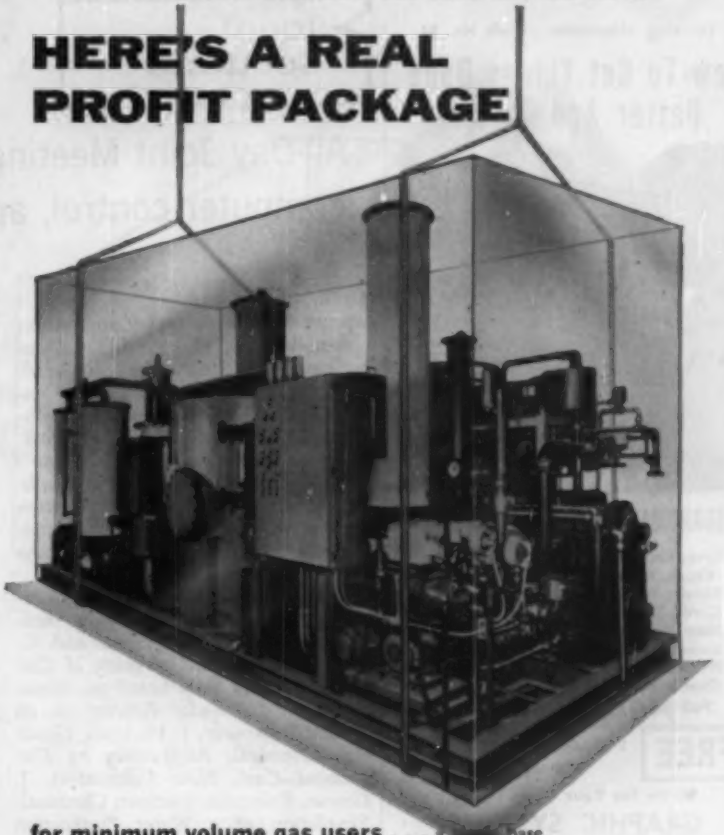

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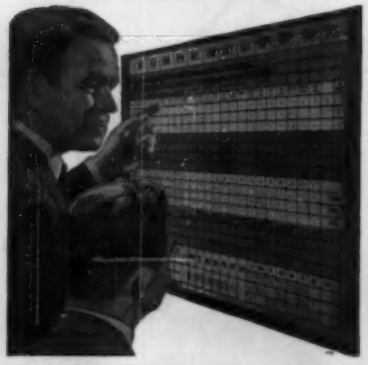

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All-Day Joint Meeting briefed on computer control, applications

An up-to-date briefing on the fast moving field of computer application was undertaken at an All-Day Symposium held in Cincinnati in April. Jointly sponsored by the **Akron, Central Ohio, Cleveland, Detroit, Northern West Virginia, Ohio Valley, Pittsburgh and Toledo Sections,** the gathering had as its over-all title *Application of Computers to the Solution of Chemical Engineering Problems.* Major aspects of the field were covered in the nine papers presented.

In addition to the introductory remarks on digital and analog computers, given by H. Jaffee and C. Evert, both of the University of Cincinnati, papers were heard on: *Simulation of a Tubular Reactor on an Analog Computer,* J. Madigan, Goodrich Chemical; *Profitability by Discounted Cash Flow Calculation,* J. Cowan, Columbia Southern Chemical; *Simulation of a Water Purification Process Using a Small Analog Computer,* W. Mink and R. Filbert, Battelle Institute; *Examples of Analysis and Correlation of Heat Transfer Data by Digital Computer,* J. Wall and E. Young, Aurora Gasoline; *Heat Extraction from Corners of Metal Castings,* K. H. Coats, U. of Michigan; *Continuous Cyclic Vacuum Crystallization Process-Heat and Material Balance,* G. Enyedy, Diamond Alkali; *Recirculation and Two Phase Flow in Vertical Thermosyphon Steam Generators,* A. Denton, Alco Products.

More on Computer Control

Chemical engineers are a key factor in process improvement by automation because the process is the most significant part of the control system, the **Bartlesville Section** (*S. J. Marwill*) was told in April. The speaker was T. C. Wherry, manager, Phillips Petroleum Instrumentation and Automation Branch, and vice president, Technical Department, ISA. Automa-

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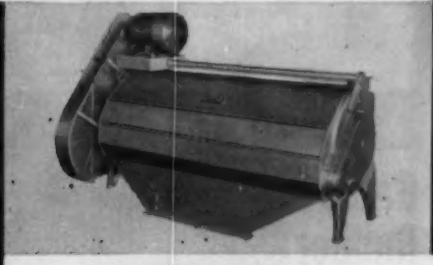

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tion, viewed by some as a movement more far reaching than the industrial revolution, is bringing about a great expansion in the field of process control. Computer controllers, he predicted, would be an important factor in future process control systems. Currently, the hardware available from instrument makers appears to be ahead of the ability of instrument users to apply it. Therefore, long studies by competent teams are necessary to develop and evaluate complex control systems. But meanwhile, important results are being obtained from the simpler computers.

Typical of the more complex analog computer, the reactor heat balance computer scans 14 process variables every 30 seconds. The input signals are obtained in electrical form from the measuring elements, and the heat balance is computed by multiplication and summation of input voltages.

Because of the fact that in the early design of new plants, proper combinations of automation in process control equipment can reduce plant costs, more active cooperation between process designers and system control engineers is essential.

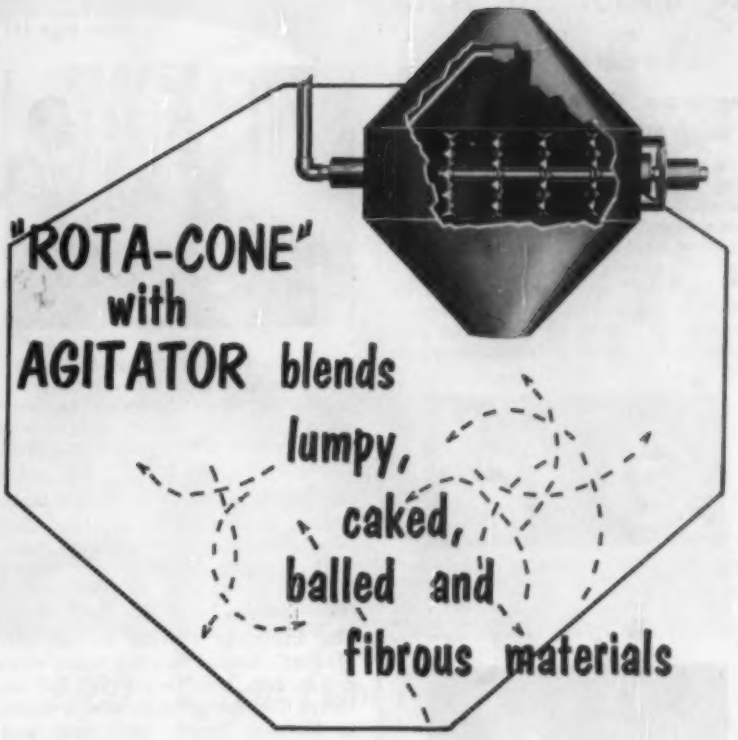
Power Conversion

Elimination of the distribution costs, a major factor in home power, is the main reason why direct conversion of heat to electric power may be economical in the home of the future, Ned S. Rasor, Atomics International told the **Southern California Section** (*Paul Armstrong*) in April. Rasor gave the meeting an outline of how the direct conversion of heat and chemical energy into electric power is accomplished. He also discussed how the several parameters of thermo-electric, thermionic, magnetohydrodynamic, thermochemical and electrochemical conversion can be varied to obtain the maximum efficiency.

Area Chemical Directory

One of our newer sections, **Fairfield County,** (*Arthur J. Weinberger*) has swung into action by putting out a directory of nearly 200 local companies related to, or of importance to chemical engineers. The first service project of the section, the directory was compiled by Leon Hecht, treasurer-elect of the group. It is expected to be a great use to the many chemically oriented business firms in the area, as well as to the professional personnel recently brought to the locality by the growth of new research and technical activities. Copies of the

continued on page 112



The Paul O. Abbé "Rota-Cone" Blender, with internal agitator, readily blends lumpy, caked, balled and fibrous materials.

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Sturtevant crushing and grinding machinery answers the long life top-load production problem for medium to small size plants. Many Sturtevants have been operating above rated capacities for more than 25 years, and *without a major repair.*

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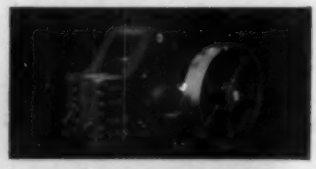
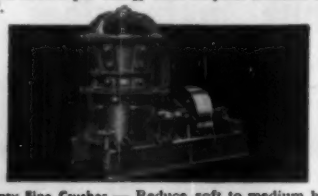
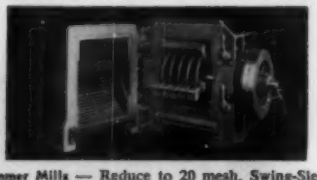


Jaw Crushers — Produce coarse (5 in. largest model) to fine (⅛ in. smallest model). Eight models range from 2 x 6 in. jaw opening (lab model) to 12 x 26 in. Capacities to 30 tph. All except two smallest sizes operate on double cam principle — crush double per energy unit. *Request Bulletin No. 062.*



Rotary Fine Crusher — Reduce soft to medium hard 3 to 8 in. material down to ¼ to 1¼ in. sizes. Capacities up to 30 tph. Smallest model has 6 x 18 in. hopper opening; largest, 10 x 30 in. Non-clogging operation. Single handwheel regulates size. *Request Bulletin No. 063.*

Crushing Rolls — Reduce soft to hard 2 in. and smaller materials to from 12 to 20 mesh with minimum fines. Eight sizes, with rolls from 8 x 5 in. to 38 x 20 in.; rates to 87 tph. Three types — Balanced Rolls; Plain Balanced Rolls; Laboratory Rolls — all may be adjusted in operation. *Request Bulletin No. 065.*



Hammer Mills — Reduce to 20 mesh. Swing-Sledge Mills crush or shred medium hard material up to 70 tph. Hinged-Hammer Pulverizers crush or shred softer material at rates up to 30 tph. Four Swing-Sledge Mills with feed openings from 6 x 5 in. to 20 x 30½ in. Four Hinged-Hammer Pulverizers with feed openings from 12 x 12 in. to 12½ x 24 in. *Request Bulletin No. 084.*

**Reports Manager W. Carleton Merrill concerning Sturtevant Swing-Sledge Mill at James F. Morse Co., Boston.*

STURTEVANT
MILL COMPANY
135 Clayton Street, Boston 22, Mass.

For more information, circle No. 40

Local sections

from page 111

Presenting Fairfield County Section local chemical industry directory to Stamford's Mayor J. Walter Kennedy (c) are Leon M. Hecht, Jr. (1) and Arthur J. Weinberger, past chairman of the section.

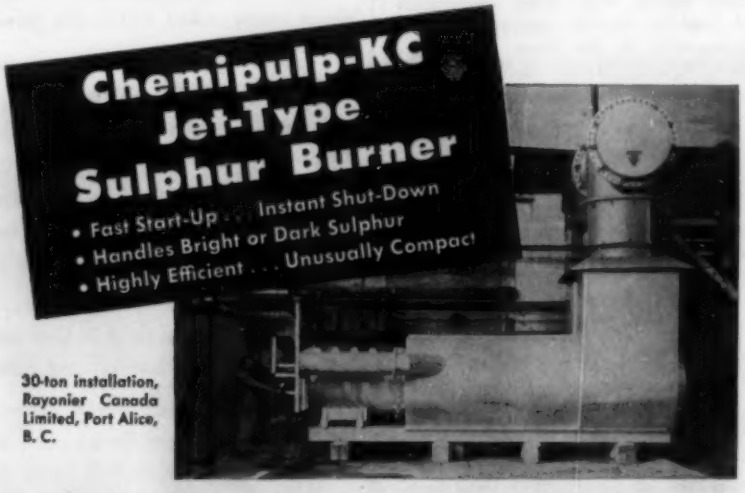
publication are being sent to all school science supervisors, newspapers and chambers of commerce in the area, and local section members.

Motel meeting

The **Peninsula Florida Section** (*H. M. Burt*) Annual Meeting was a rousing success, both technically and socially. The group takes over a motel in Daytona Beach, each year, and spends two and half days swimming, vacationing with their families, *and* listening to technical papers which bring them up-to-date on developments in the field. Of particular interest on the eight-paper program were *The Chemical Engineer's Stake in Systems Engineering*, B. Fairchild, U. of Florida, and *Planning and Scheduling of Capital Engineering Projects*, E. Loyless, St. Regis Paper. Winding up the technical program was presentation of a prize-winning design problem by a U. of Florida student.

Also meeting

A joint meeting of **Indianapolis, Lafayette,** and **Terre Haute Sections** (*W. E. McCoy*) in March heard Jerry McAfee in a talk on A.I.Ch.E. J. Anderson, Union Carbide, spoke on *Liquid Extraction*. . . The **Fairfield Country Section** (*J. Witheford*) featured a talk by R. Fremed, associate editor, *Chemical Engineering*, on *Professionalism vs. Unionism*. Occasion was April meeting. . . Ladies' Night at the **North Jersey Section** (*S. A. Savitt*) deserted chemical engineering for a social June meeting. . . Annual plant inspection trip of the **Rochester Section** (*M. Mulman*) took place in April, when the group toured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• Fast Start-Up . . . Instant Shut-Down
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30-ton installation, Rayonier Canada Limited, Port Alice, B. C.

In the Chemipulp-KC Burner, molten sulphur is sprayed into the burner as a fine mist; heated secondary air is then introduced in several stages, resulting in clean, efficient burning. The burner quickly reaches its operating temperature of about 2400°F., minimizing production of SO_3. Operates efficiently at all SO_2 concentrations between 12% and 18½%. At 2100°F, bitumen in dark sulphur is completely burned.

Available in a range of sizes up to 50 tons of sulphur per day and each size will produce SO_2 gas efficiently through a wide operating range. Compact design and flexibility of layout permit installation in limited space.

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For more information, turn to Data Service card, circle No. 5

Bristol Laboratories. . . Underground storage of petroleum gases at Shell Oil's butane caverns was discussed at the **Alton-Wood River Section** in April. Speaker was A. L. Calcaterra, project engineer for construction of the cavern at the Shell refinery. . . A topside view of the use of computers in process industries was presented to the **Philadelphia-Wilmington Section** in April. J. Aronofsky, manager, Computer Center, Socony Mobil Oil, showed how linear programming can be used to optimize plant operations . . . Dunlop Tire & Rubber, Tonawanda, N.Y., was the scene of the **Western New York Section** (*Reed E. Garver*) April tour. Earlier, the group heard Alfred A. Adler, staff consultant in flight mechanics, Bell Aircraft, talk on space flight . . . How to achieve more productive experimentation was M. Dorian Shainin's topic at the **Western Massachusetts Section** (*R. Simon*) in May. He dealt with the strength and weakness of the scientific method, and how statistical techniques of interest to chemical engineers can add objectivity to it. Simon is vice president, Rath and Strong consultants . . . **Northern California Section** (*R. C. Hungerford*) toured Dow Chemical's Pittsburg, Calif. plant in April. . . The **Baltimore Section** (*Philip Messina*) viewed the Kennecott Refining Corp. on its annual plant trip in May . . . The (Boston) **Icthyologists** wound up activities for the year with an "Annual Last Splash" dinner-dance in May . . . The USSR and the importance of science and technology there were discussed by Norman Neureiter at the **South Texas Section** (*G. H. Cummings*) in May. A research chemist at Humble Oil & Refining's Baytown, Texas, Research Center, Neureiter also teaches Russian in the University of Houston evening session. He served as a guide last year at the American National Exhibition in Moscow.

Rapidly growing markets for higher acrylates have prompted Celanese Corp. plans to double capacity for 2-ethylhexyl acrylate, butyl acrylate and glacial acrylic acid. Facilities at the company's Pampa, Texas, plant will produce 14 million pounds annually.

An electrolytic manganese metal manufacturing plant, 10 million pounds a year capacity, is planned at Aberdeen, Miss., by American Potash & Chemical. The $5 million facility is located adjacent to the company's sodium chlorate plant. Completion is scheduled for late 1961.

For more information, turn to Data Service card, circle No. 2

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people in management and technology

Antoine Marc Gaudin has been elected chairman of the Engineering Foundation, UET research department, "for the furtherance of research in science and engineering, and the advancement in any other manner of the profession of engineering and the good of mankind."

Gaudin is the Richards Professor of Mineral Engineering at M.I.T. He also acts as a consultant to industry and government both here and abroad. Most known for his contributions to the theory and practice of flotation, he is also distinguished in the fields of hydrometallurgy, ion-exchange, solvent extraction, and metallurgical applications of radioactive isotopes. Gaudin is the author of two books, *Principles of Mineral Dressing*, and *Flotation*, and numerous technical papers. He was cited in 1957, by AIME for his leadership and direction in the development of leaching and recovery techniques for low-grade uranium ores.

Gaudin received his bachelor's degree in science from the University of Paris, and the degree of Engineer of Mines from Columbia University. He was Associate Professor of Mechanical Engineering at the University of Utah, and Research Professor of Mineral Dressing before going to M.I.T. in 1939.

Seymour Calvert, associate professor of Chemical Engineering at Case Institute of Technology, has been appointed chairman of the newly formed Air Pollution Advisory Board for the city of Cleveland. Calvert is currently conducting a Basic Study of Air Pollution Wet-scrubbers under a grant from the U. S. Public Health Service.

Frank Bockhoff, assistant professor of Chemical Engineering, Fenn College, received the 1960 Young Engineering teacher Award of the American Society for Engineering Education. Bockhoff is co-author of *Welding of Plastics*. He also wrote the section on

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Gate Valve

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plastic welding in *Modern Plastics Encyclopedia*. The Award is based on recommendations by the deans of Ohio's thirteen engineering colleges.

An award for distinguished service in engineering was presented to **Charles J. Haines** by the University of Missouri. The president of Chemetron was cited for his managerial ability in bringing together the talents and resources essential to the growth and expansion of industrial enterprise, and his organizational ability in forming a strong and widely diversified company. He received a bronze medal at a convocation of the College of Engineering.

Presson S. Shane was elected vice president, Atlantic Research Corp. He joined the company in 1958 as director of the Solid Propellant Division. Shane's responsibilities now include the Solid Propellant Division and Desomatic Products, Inc. a subsidiary of Atlantic Research.

George J. Odom has been elected president, Maine Association of Engineers. Odom, operations manager, Chemetron, Searsport, Maine, is the first chemical engineer to serve in this post.

Paul J. Flory attended the International Symposium on Macromolecular Chemistry, held in Moscow in June. Flory, executive director, research, at Mellon Institute, was U.S. National Representative, Committee on Macromolecular Chemistry, National Research Council.

Edgar B. Gutoff has joined Polaroid Corp., Waltham, Mass., as an emulsion development engineer. He was formerly with Ionics, Inc.

Douglass J. Wilde has been granted a Fulbright Lectureship for 1960-61. He will teach Operations Analysis in the Chemical Engineering Department of the Ecole Superieure des Industries Chimiques, which is part of the University of Nancy in France. Presently Wilde is a lecturer in chemical engineering at the University of California.

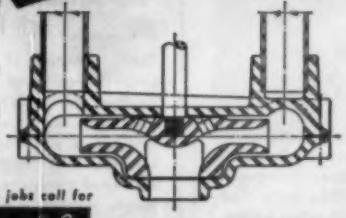
Ernest H. Volwiler won the 1960 Gold Medal of the American Institute of Chemists. The award was given in recognition of his outstanding contributions to the pharmaceutical indus-

continued on page 116

gritty, corrosive solution doesn't faze these Nagle® pumps

These two 5" type "SWOB" Nagle vertical shaft centrifugal pumps are giving excellent service in a Michigan metallurgical plant. They are designed to give years of service where ordinary pumps would give only months of service. All submerged parts are of corrosive and abrasion resistant materials. There are no bearings below the floor plate. No stuffing box to worry about. Pump entrance is at bottom of casing so that solids cannot settle around impeller when pump is not operating. Nagle "SWOB" pumps are available 1" to 8", capacities to 1800 GPM, heads up to 100'. Many of these pumps are cutting costs in chemical and metallurgical plants.

Nagle Pumps, Inc., 1255 Center Ave., Chicago Heights, Ill.



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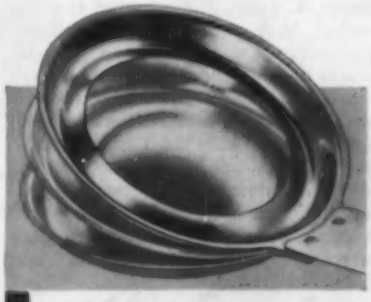

A holddown ring is the added feature that gives the new Fike CPV rupture disc unit a distinct advantage over conventional units. The close fitting holddown ring holds the rupture disc snugly to the vacuum support. This reduces wrinkling and possible fatigue failure in cycling vacuum and pressure service. It also protects fragile discs from being cut by excessive tightening.

The Fike CPV unit is more rugged than conventional rupture discs of equal rupture pressure. It is more easily handled and there is less danger of damaging the rupture disc during installation from over torque or slight inclusion of foreign matter on seating surfaces of flanges.

Sizes range from 1" to 24" with rupture pressure ranging from 4 to 850 lbs. PSIG at 72° F. Metals available depending on size, include aluminum, copper, silver, nickel, monel, inconel and stainless steel. Any of the above materials furnished with plastic dispersion coats or sheet plastic lamination for various corrosive conditions.

Send for the new complete catalog on Fike Rupture Discs.

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Blue Springs, Missouri
(Dept. C.E.P.)

For more information, turn to Data Service card, circle No. 9

For more information, circle No. 59

People

from page 115

try and for his great service as a leader in the chemical profession. Volwiler is chairman of the board of Abbott International and a consultant of Abbott Laboratories, North Chicago, Illinois. He is credited with developing manufacturing techniques for butyn, nembutal, and pentothal. During World War II, Volwiler developed improved processes for the production of sulfa drugs and penicillin.

James A. Lane, a member of the director's staff at Oak Ridge National Laboratory, was one of a United States technical delegation to Yugoslavia in May. They visited several nuclear research installations and held consultations with the Yugoslav Federal Commission for Nuclear Energy, on developments in Yugoslavia, and on technical matters. The two week visit by the American team returned a similar visit made to the U.S. by a Yugoslav group.

Edward C. Page, Jr. has joined J. T. Baker Chemical as assistant to the director of manufacturing. He was formerly first vice president, Henry Bower Chemical Manufacturing.

Stuart McLain and **Walton A. Rodger** have formed a new consulting firm, McLain and Rodger Associates. They will specialize in reactor design and operation, nuclear fuel cycles and radioactive waste disposal. McLain, who has been in private consulting recently, was in 1956-57 associate director of the Argonne National Laboratory in charge of the educational program. Rodger was special consultant to the Joint Congressional Committee on Atomic Energy at the Waste Disposal Hearings last year. He was associate director, Chemical Engineering Division, Argonne National Lab.

Necrology

Leonard P. St. Clair, 89. Formerly president of Union Oil Co., St. Clair began his association with the company in 1909, as representative of the independent producers in the San Joaquin Valley. He was president of the Independent Oil Producers' Agency until 1957. Elected president of Union Oil in 1930, he was board chairman until retiring from the post in 1939.

Robert M. Boarts, Jr., 56. Head of the Department of Chemical Engineering, University of Tennessee. Boarts had been on the faculty of the University since 1934. He had also acted as consultant for T.V.A., the Bureau of Mines, and Oak Ridge National Lab. He received a B.S. Ch.E. from Lafayette, and M.S. and Ph.D. from the University of Michigan.

E. Clinton Bowen, 53. President of Bowen Corp., general engineering firm founded by him in 1952, he did much work on applications of vapor compression distillation to industrial waste recovery. He was a member of the technical section, Canadian Pulp and Paper Association. Active in TAPPI, Bowen was secretary of its Chemical Engineering Committee, and also held membership in the Pulp and Paper Foundation, University of Maine. Bowen served as a symposium chairman at the A.I.Ch.E. Annual Meeting in Boston in 1956, heading "Chemical Engineering in the Pulp and Paper Industry." Active in A.I.Ch.E., Bowen was influential in furthering work done by the Institute concerning chemical engineering in the pulp and paper field.

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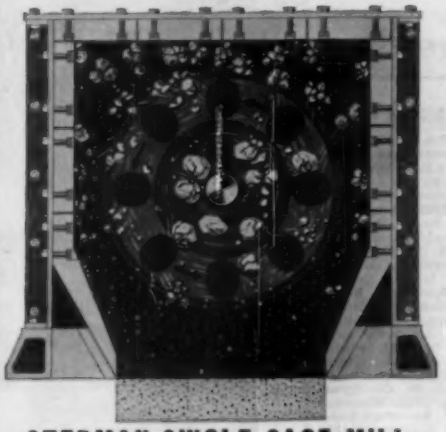

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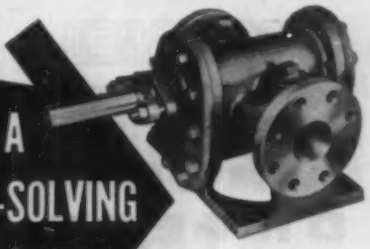

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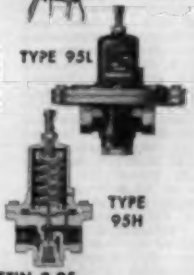

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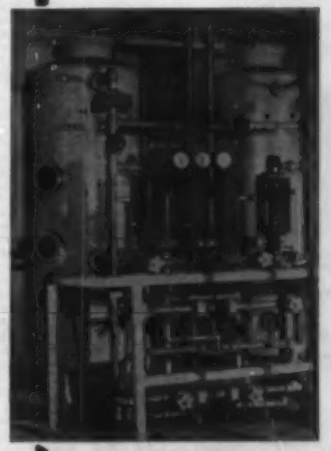

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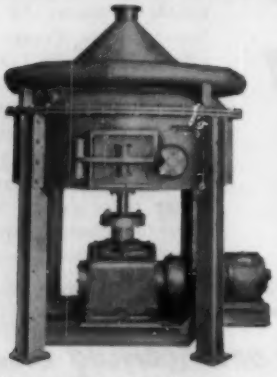
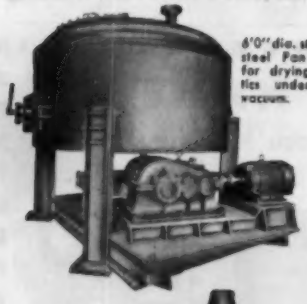
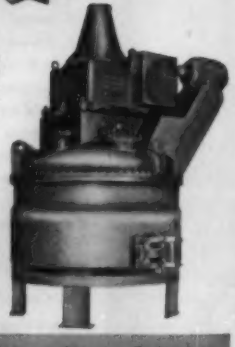


5'2" dia. stainless steel Pan Dryer with scraped and jacketed bottom. Used for drying an organic solvent from a naval stores product.



6'0" dia. stainless steel Pan Dryer for drying plastics under high vacuum.



8'0" dia. cast iron Thermacoil Pan Dryer for processing highly corrosive and abrasive materials.

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PAN DRYERS

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future meetings

1960—MEETINGS—A.I.Ch.E.

• **Cambridge, Mass., Sept. 7-9, 1960. M.I.T. Joint Automatic Control Conference.** Sponsored by A.I.Ch.E., AIEE, IRE, ASME, ISA. For A.I.Ch.E. info refer to: W. H. Abraham, Eng. Exp. Sta., Dupont, Wilmington 98, Del.

• **Tulsa, Okla., Sept. 25-28, 1960. Hotel Mayo. A.I.Ch.E. National Meeting.** Gen. Chmn.: E. W. Kilgren, Pan Am. Petrol Corp, Tulsa, Okla. Tech. Prog. Chmn.: K. H. Hachmuth, Phillips Petroleum Co., Bartlesville, Okla. See page 100.

• **Longview, Wash., Oct. 7, 1960. Pacific Northwest Section A.I.Ch.E. One-Day Regional Meeting** on general topics. Mtg. Chmn.: R. O. Bathiany, Weyerhauser Co., Longview.

• **Washington, D.C., Dec. 4-7, 1960. Statler Hotel. A.I.Ch.E. Annual Meeting.** Gen. Chmn.: J. L. Gillman, Jr., 1700 K St., N. W., Wash. 6, D.C. Tech. Prog. Chmn.: D. O. Myatt, Science Communication, Inc., 1709 Wisconsin Ave., N.W., Wash. 7, D.C. **Air Pollution**—A. J. Teller, U. of Florida, Gainesville, Fla. **Unsteady—State Instrumentation**—T. J. Williams, Monsanto Chem. Co., St. Louis, Mo. **Fluid Dynamics**—A. C. Acrivos, U. of California, Berkeley, Calif. **Information & Communications**—R. O'Dette, NSF, Wash., D.C. **Nuclear Reactor Operations**—R. L. Cummings, Atomics International, Canoga Park, Calif. **Nuclear Chemical Plant Safety**—C. E. Dryden, Ohio State U., Columbus, O. **Phase Transitions**—G. Bankoff, Northwestern U., Evanston, Ill. **Sales Overseas**—J. Costigan, The Sharples Corp., 501 Fifth Ave., New York 17, N.Y. **Chemical Engineering—A Vital Link in Broadening the Uses of Agriculture Crops**—J. E. Simpson U.S.D.A. **Chemical Warfare—Dispersal of Materials in Aerosol Form**—L. E. Garone, Army Chem. Corps. **Role of the Chemical Engineer in Environmental Health Engineering**—W. L. Faith, Air Pollution Foundation, 2556 Mission St., San Marino, Calif. **Feeding, Clothing, and Protecting the Combat Soldier**—Leo Spano, Quartermaster R&Eng. Command, Natick, Mass. **Phenomena Affecting Materials in Extreme Environments**—J. Hearne, Air Force R&Eng. **Impact of Govt. Programs on Chemical Engineering Education**—W. K. Davis, Bechtel Corp. **Toxic Plant Construction**—L. E. Garone, Army Chem. Corps. **Potentialities of Fuel Cells as Power Sources**—P. Greer, Army OOR. **Saline Water Conversion**—J. J. Strobel, OSW, Dept. Int. **Chemical Engineering in the Mineral Industry**—H. Perry, Chf. Bit. Coal Res. Br., U.S. BuMines. **Rocket Propellants**—W. E. Sheehan, DDRE. **Economic Evaluation of New Processes**—J. H. Hirsch, Gulf R&D Co., P.O. Drawer 2038, Pittsburgh 30, Pa. **New Crystallization Techniques**—H. M. Schoen, American Cyanamid Co., 1937 W. Main St., Stamford, Conn. **Heat Transfer**, Papers requested—M. Altman, Gen. Elec. Co., 3198 Chestnut St., Philadelphia, Pa.

1961—MEETINGS—A.I.Ch.E.

• **New Orleans, La., Feb. 26-March 1, 1961. Hotel Roosevelt. A.I.Ch.E. National Meeting.** Gen. Chmn.: O. F. Wiedeman, Cyanamid, New Orleans, La. & H. E. O'Connell, Ethyl Corp., Baton Rouge, La. Tech Prog. Chmn.: A. L. Regnier, Petroleum Chem., P.O. Box 6, New Orleans 6, La. **Brainstorming Technical Problems**—G. C. Szego, Space Technology Labs., P.O. Box 95001, Los Angeles 45, Calif. **Kinetics of Catalytic Reactions**—M. Boudart, Princeton U., Princeton, N.J. **Petrochemicals—Future of the Industry on the Gulf Coast**—J. A. Sherred, Monsanto Chem. Co., St. Louis 66, Mo. **Filtration**—F. M. Tiller, U. of Houston, Houston, Texas. **Settling**—A. G. Keller, La. State U., Baton Rouge, La. **Future Processing Technology in the Petroleum Industry**—A. F. Kauiakis, Process Res. Div., ESSO. **Education and Professionalism**—R. P. Dinsmore, Goodyear Tire & Rubber Co., Akron 16, O. **Mathematics in Chemical Engineering**—R. L. McIntire, Mathematical Eng. Assoc., 3108 Sweetbriar, Fort Worth 9, Tex. **Evaluation of R&D Projects**—L. A. Nicolai, 239 Parsonage Hill Rd., Short Hills, N.J. **Liquid—Liquid Extraction**—R. B. Beckman, Carnegie Tech., Pittsburgh 13, Pa. **New Petrochemical Processes in the Area**—B. G. Caldwell, Dow Chem. Co., Plaquemine, La. **Materials of Construction**—R. V. Jelinek, Syracuse U., Syracuse, N.Y. **Thermodynamics**—J. J. Martin, Ch.E. Dept., Univ. Calif., L.A. 24, Calif. **Use of Probability Mathematics in Economic Evaluation**—A. O. Bates, Atlas Powder Co., New Murphy Rd., Wilmington 99, Del. **International Chemical Picture**—L. Resen, CEP. **Selected Papers**—E. Mannings, Shell Oil Co., Norco, La.

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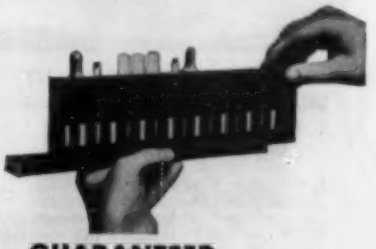

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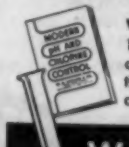

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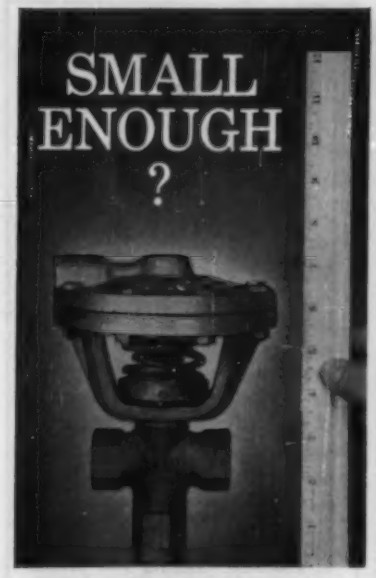

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future meetings

continued

Deadline for papers: Sept. 5, 1960.

• **Cleveland, O., May 7-10 1961. Hotel Sheraton, Cleveland. Joint A.I.Ch.E. National Meeting with Ch.E.Div. C.I.C.** Gen. Chmn.: H. Pfersheimer, Jr., Standard Oil Co. (Ohio), Cleveland. O. Tech. Prog. Chmn.: R. P. Dingmore, Goodyear Tire & Rubber Co., Akron 16, O. **Petrochemicals as Starting Materials for Polymers**—I. F. Marck, A. D. Little, 30 Memorial Dr., Cambridge 42, Mass. **Fluid Mechanics**—W. H. Gauvin, McGill Univ., Montreal, Que. **Optimum Utilization of Pilot Plants**—J. T. Cumming, School Eng., Penn College, Cleveland 15, O. **Process Dynamics (Theoretical)**—R. M. Butler, Imperial Oil Co., Sarnia, Ont. **Synthesis Processes for Isoprene**—T. A. Burtis, Houdry Process Corp., 1528 Walnut St., Phila. 2, Pa. **Radioactive Materials for Process Control**—J. R. Bradford, College of Eng., Texas Tech. College, Lubbock, Tex. **Process Dynamics (Applied)**—L. M. Naphtali, Ch.E. Dept., Brooklyn Polytech., Brooklyn, N. Y. **New Synthetic Rubber Types**—P. M. Lindstedt, Goodyear Tire & Rubber Co., Ch.E.Div., Akron 16, O. **Coalescence**—R. Kintner, Illinois Inst. Tech., Chicago 16, Ill. **Management Criteria for Capital Investment**—C. F. Prutton, Food Machy. & Chem. Co., 161 E. 42d St., New York 17, N. Y. **Ch.E. in Metal Refining**—W. M. Campbell, Chem. & Met. Div., Atomic Energy of Can., Chalk River, Ont. **Heavy Metal Mfr.**—L. P. Scoville, Diamond Alkali, Union Commerce Bldg., Cleveland 14, O. **Applications of High Speed Photography**—A. L. Johnson, Univ. of Toronto, Toronto 5, Ont. **Bulk Fibrous Materials**—R. M. Christiansen, Stearns-Roger Mfg. Co., Denver, Colo. **Pulp and Paper**—J. L. McCarthy, Univ. Washington, Seattle 5, Wash. **New Research Techniques**—D. Hyman, Cyanamid, 1937 W. Main St., Stamford, Conn. **Mixing-Fundamentals**—J. Y. Oldshue, Mixing Equipment Co., P. O. Box 1370, Rochester, N.Y. **Mixing-Applications**—E. E. Ludwig, Dow Chemical, Freeport, Tex. **Cash Flow Methods in Economic Analysis**—D. D. MacLaren, Esso **Research & Eng.**, P. O. Box 216, Linden, N.J. **General Papers**—D. J. Porter, Diamond Alkali, P. O. Box 348, Rech. Center, Painesville, O. **Student Program**—H. B. Kendall, Case Inst., 10900 Euclid Ave., Cleveland, O. Deadline for papers: Dec. 7, 1960.

• **Lake Placid N. Y., Sept. 24-27, 1961. Lake Placid Club. A.I.Ch.E. National Meeting.** Gen. Chmn.: B. I. MacDonald, Jr., G. E. Waterford, N. Y. Tech Prog. Chmn.: E. R. Smoley, 30 School Lane, Scarsdale, N. Y. **Control of Corporate Investment Costs; Chemical Engineering in the Photographic Industry; Techniques Used to Improve Profitability of Petroleum Processes; Recent Developments in Mechanisms of Chemical Reactions; Chemical and Physical Properties of Materials at High Temperature; Radiation Effects; Synthetic Natural Rubber; Chemical Engineering in Management; Materials Handling; Petrochemicals in the 1960's; World Wide Sales Challenge of the Sixties in the Chemical Process Industry; Economics of Equipment Selection; Economics Theories Applied to Growth Industries; Market Development in the C. P. I.**

• **New York, N. Y., Dec. 3-6, 1961. Hotel Commodore. A.I.Ch.E. Annual Meeting.** Gen. Chmn.: L. J. Coulthurst, Foster Wheeler Corp., 666 Fifth Ave., New York 19, N. Y. Tech. Prog. Chmn.: A. V. Caselli, Shell Chem. Corp., 50 W. 50 St., N. Y. 20, N. Y. **International Chemical Engineering; Utilization of Technical Personnel; U. S. Chemical Industry; Fluidization; High Viscosity Fluids—Design Aspects; Physical and Transport Properties; Polymerization Kinetics and Catalyst System; Heterogeneous Catalysis and Chemisorption; Heat Transfer—Phase and Chemical Change Systems; Solid State Principles & Applications; Flame Theory and Plasmas; Water Pollution; Petroleum Processes; Petrochemical Processes; Nuclear Technology; Recent Advances in Ferrous Pyro-Metallurgy; Hydro-Metallurgy; Pilot Plants; Polymer Handling Equipment; Process Dynamics, Control and Simulation; Radiation and Furnace Design.**

SPECIAL ANNOUNCEMENT

• **Chicago, Ill., Sept. 15-16, 1960. Morrison Hotel. 8th Annual Engineering Management Conference. Sponsored by A.I.Ch.E., AIEE, AIME, ASCE, ASME, AIIE, & IRE.** Subject is **Managing Tomorrow.** Four-part breakdown is as follows: **Impinging Forces, New Requirements and New Aids for Managers, Impact on Professional People, & Impact on Education.** Arrangements chm.: L. A. Spangler, Westinghouse Electric Corp., Merchandise Mart, Chicago. Registrations can be made through E. C. Rudolphy, U. S. Steel Corp., 3429 E. 67th St, Chicago 17, Ill.

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SITUATIONS WANTED
A.I.Ch.E. Members

CHEMICAL ENGINEER—B.S.Ch.E. 1948, P.E., age 34, family. Experience in applied research and development, heat transfer technical sales, refinery processes and maintenance. Desire responsible position in product development, technical sales, or technical service. Resume on request. Box 7-8.

PRODUCTION MANAGER—Twenty-five years' of successful operating and top management experience in heavy chemical and in hydrometallurgy industries. Intensive background in maintenance, construction, plant engineering, labor relations, and cost analyses. Box 8-8.

MARKET RESEARCH—B.S.Ch.E. 1952; M.I.T., M.B.A., of N.Y.U. 1960. Age 30, family. Four years' experience as pilot plant ship supervision, and process development engineer. Two years' experience market analyst. Prefer N.Y.C. area. Box 9-8.

CHEMICAL ENGINEER—B.Ch.E. 1958, age 24. Two years' experience as Project Engineer in process development of toxic agents for the U. S. Army. Desire position in production or development. Box 10-8.

TECHNICAL MANAGER—Twenty years' experience alternately in sales, research and development, mainly to petroleum processing industry, primarily catalysts. Caltech graduate. Seek wider responsibilities. Box 11-8.

CHEMICAL ENGINEER—B.S. 1951, age 32, family. Diversified experience in ammonia, methanol, formaldehyde, resins. Present position at top management level. Seek challenging position North or Western States. Available Jan. 1961. Box 12-8.

DEVELOPMENT MAN—Responsible for consumer product which has reached sales of $25,000,000/year in five years. Most recent inventions in process machinery field. Similar sales expected. $35,000. Box 13-8.

(continued on page 122)

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Cleveland 14, Ohio

SITUATIONS WANTED
A.I.Ch.E. Members

(continued from page 121)

CHEMICAL ENGINEER—B.Ch.E. 1958. Minor in Nuclear Engineering. Some courses towards M.S. in Industrial Management. Family. Have been desk bound first with government agency in nuclear field, and now with a small nuclear division of a large company. Desire process engineering or technical service position offering professional growth. Box 14-8.

CHEMICAL ENGINEER—B.S.Ch.E., family, age 42, registered. Eight years' broad experience in nuclear R & D, plant construction, start-up and operation as production supervisor. Keen interest human relations. Management potential. South preferred. Will relocate. Box 15-8.

PROCESS (OPERATIONS) ENGINEER—Age 35. Ph.D. (Ch.E.), minor in industrial management. Six years' experience in directing and operating of pilot plants. Desire direct contact with operating personnel in pilot plant, semi-works, or small production organization. Prefer Chicago area but will relocate. Box 16-8.

CHEMICAL ENGINEER—Ph.D., age 28. Three years' R & D and Process Engineering experience in the plastics and chemical engineering fields. Desire a responsible position to apply a broad technical background to R & D problems. Box 17-8.

ENGINEERING SUPERVISOR—Imaginative leadership in supervision of research, development, design, execution of chemical processing plants. Outstanding record of accomplishment during twenty years with top corporation. B.Ch.E. '40, P.E., earning $15,400 desire growth opportunity. South preferred. Box 18-8.

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CHEMICAL ENGINEER—29, married, B.S.Ch.E. 1958. Two years' experience in developing government chemical specifications. Would like to start out in process engineering with private industry. Graduated in upper quarter of class. Box 22-8.

RESEARCH ADMINISTRATOR — Chemist Ph.D., thoroughly experienced research management seek responsible position pharmaceutical, chemical, or fermentation industry. Sixteen years supervision and administration of research, development, pilot plants. Box 23-8.

SITUATIONS WANTED
A.I.Ch.E. Members

LATIN-AMERICAN ASSIGNMENT—desired by B. S. chemical engineer, speaks Spanish, familiar with Portuguese, age 35, family, experienced in organic chemical operations, process development, plant start-up and technical service, production supervision. Box 24-8.

CHEMICAL ENGINEER—B.S.Ch.E., age 29. Six years' experience major chemical company; in pilot plant, plant development, cost studies, engineering liaison with design division, new plant start-up. Job must have responsibility with advancement potential. Box 25-8.

PROCESS ENGINEER—B.S.Ch.E. 1949, M.Ch.E. 1952, age 38. Diversified experience in pilot plant, process development, design, project engineering in organic and petrochemical field. Desire position in process design, economic evaluation, or project engineering. Box 26-8.

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CHEMICAL ENGINEER—B.Ch.E., married. Two and one half years' experience in continuous, emulsion, solution, and bulk polymerizations, special equipment design work, reactive inks, rapid curing of coatings, coatings evaluation. Studying for M.S. in Industrial Management. Desire R&D position in N.Y.-N.J. area. Box 30-8.

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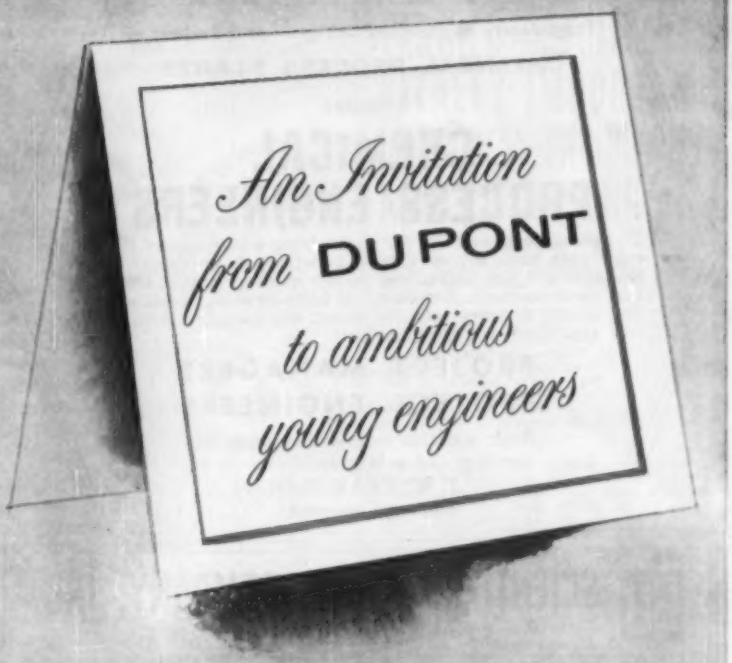

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The rapid, even meteoric development of the petro-chemical industry in the past decade has enhanced the role of importance played by engineering specialists with each step of its progress. Today, the engineer who is equipped with knowledge, study, training and experience in some specific phase of the processing cycle finds himself in an extremely favorable position and nowhere is this more obvious than in the realm of process engineering and estimating.

But industry has a new concept of a "specialist" in the complex of today's business society. He must have a broad concept of the total effort of his company, and cannot be content simply with "doing his job better than anyone else can." Since companies today, large or small, see their profits shrink as costs increase, the engineering specialist must apply his special knowledge or skill to the task at hand with diligence and genius, but with a practiced eye on the effect of his specialty on the profit structure of his company (or his client, or customer, if he is a consultant or supplier).

A generation ago, the "all-round" process engineer was himself a specialist, experimenting, researching, studying developing—combining "educated guessing" with engineering judgment to solve the problems presented. His was the task of dealing with all phases of an engineering process — design, estimating, operating — material and heat balances, temperatures, pressures, flow quantities, the design of special equipment, specification of instruments and controls, stress analysis, corrosion control, etc., etc.

Today, with larger, more complex plants — especially in continuous flow processes — and with greater expense involved in more complicated processes, many specialties have grown from the earlier process engineer specialist, resulting in accelerated advances in each specific field, as demands for more rapid progress are met. The petro-chemical industry in particular has demanded, attracted, developed — and paid for — men of unusual ability and broad vision, expert in their specific fields, communicative, articulate, aware and appreciative of the problems of other specialists as well as of business in general — and therefore more "profitably productive" for their companies. The search for these men increases with each new demand on the industry.

What training, background, experience is needed by today's process engineer to become a specialist? What is required in addition to an extraordinary interest and aptitude for a specific phase of engineering? There are certain technological requirements related to each field, of course, and they are fairly well-defined in each phase, but there are other more general, yet equally important, qualities and attributes on which the aspiring specialist must pass muster.

Space limitations in this column do not, of course, permit a full treatment of this important subject, but it has been covered more completely and in greater detail in a booklet entitled "Engineering Specialties: A Challenge," and complimentary copies are available to you by writing to: WESTERN SUPPLY COMPANY, HEAT EXCHANGER DIVISION, P. O. BOX 1888, TULSA, OKLA. — and remember, our engineers specialize in designing, estimating and building the heat exchangers in your future.

For more information, Circle No. 96

News and Notes of A.I.Ch.E.

Report from Mexico

Council of A.I.Ch.E. met in Mexico City just prior to the meeting there and rapidly cleared up many items on the agenda in order to enjoy every minute of what was an outstanding international meeting. Before I get on to some of the things Council did, this is a good time to acknowledge publicly the exceptional achievements of our colleagues in Mexico. All the officers and members of the Instituto Mexicano de Ingenieros Químicos and their wives strove hard to make the meeting the great success it was.

If I were asked to point to the highlight of the meeting, I must confess that what stirred me most were the beautiful folk and Indian dances put on during the Noche Mexicana on Tuesday evening, June 21. The performance, which was sponsored by Pemex, was climaxed by a stirring display of Aztec dances put on by a troupe of Indians in full costume who literally had the Hotel del Prado shaking from the stamping and gyrations of a mighty forceful presentation of early American rhythm.

The second most exciting event, which was arranged just for the chemical engineers, was the bull fight . . .

the first that many of the Americans had seen. It was during this event that one member said to me, "This is the best meeting the A.I.Ch.E. has ever put on."

The only thing wrong with the statement was the fact that A.I.Ch.E. did not really put it on; it was the work of a superb group of gentlemen from Mexico, and we tip our hat to them for it. This success actually leaves me with a problem, because I am certain there will be a great number of requests for additional international meetings such as this, and the problem is to fit them into our schedule.

New computer program

Now for Council actions. Council is in the process of approving a very special program for computer estimation of physical data. This was presented by R. P. Genereaux, Director, and W. M. Carlson, Chairman of the Committee on Machine Computation. There are still some details that must be cleared up before a full report of the program is available, but much of the Council meeting in Mexico City was given over to a very careful consideration of the problems involved in this proposal, along with the approval of the beginnings of a special project by the Standards Committee, J. C. Lawrence, Chairman, to study a standard system of indexing and retrieval of engineering information. (More on Council in Sept.)

A.I.Ch.E. wants you

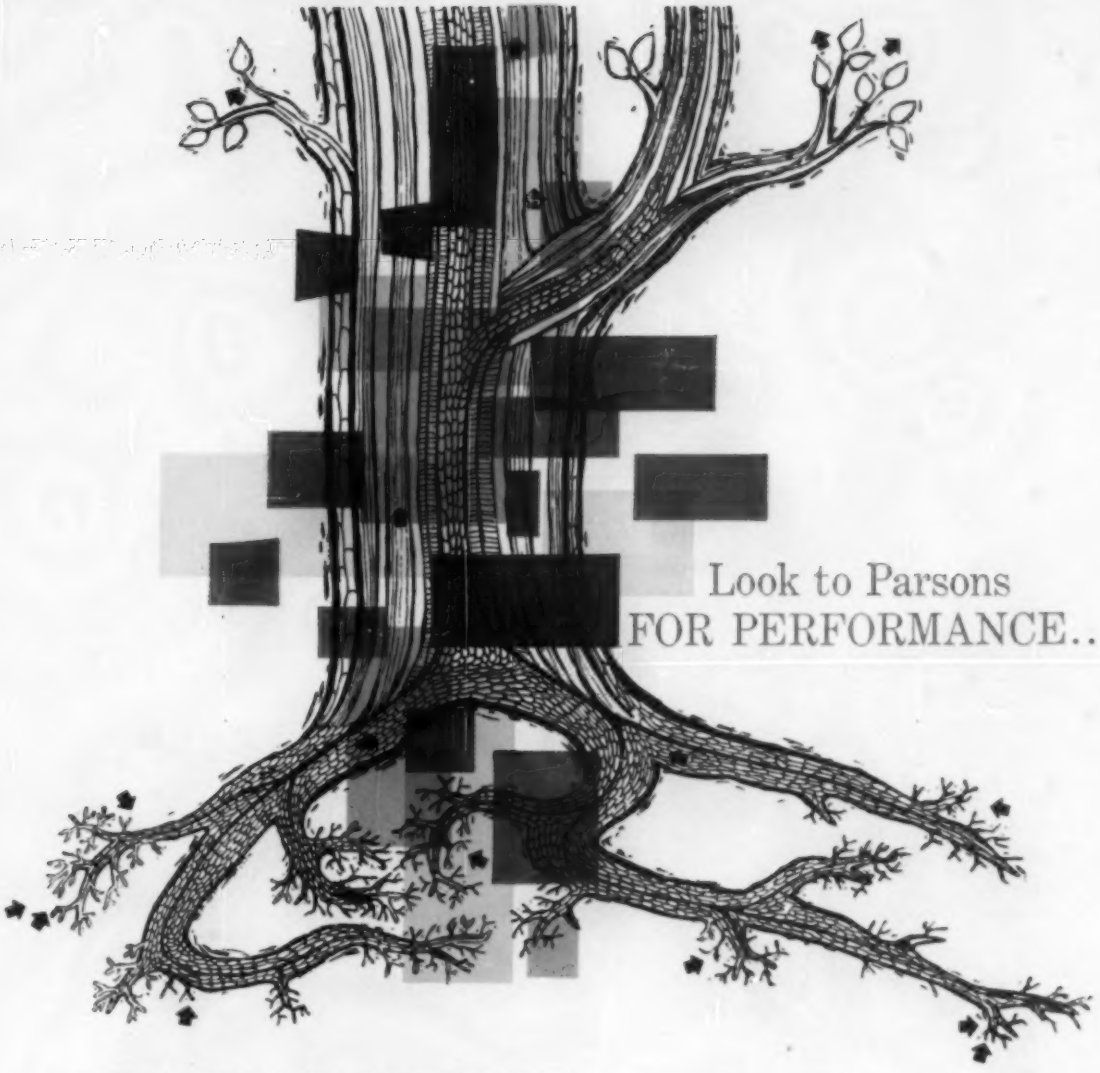
Although membership results so far this year are good, this is nevertheless a note of appeal to all the members to help support the fine efforts of the membership group. It's not always easy these dollar-and-cents-days to convince fellow-chemical engineers of the values of membership; yet if we are to achieve our purpose as a unified profession, if we are to serve chemical engineers with the magazines, meetings, lectures, etc., that they need, we're going to have to have *all* eligible engineers. The next time a Membership Committee man comes along to ask you to do your part, please pitch in; the next time someone says to you, "Why should I join A.I.Ch.E.?" speak right up and tell him why. And if you don't know why, write us and we'll certainly give you a lot of reasons. . . . Members often raise their eyebrows when in speaking before Local Sections I casually mention the need for more members, more money, etc. Yet few realize the drains on a nonprofit organization such as ours. We try to cut as closely as possible the cost of everything we do. The accounting figures on the Special Lectures, for instance, indicate that, when all costs are considered, A.I.Ch.E. lost $1,000 on each of the lectures despite the fact that we charged a sizable fee. We want to continue these activities, and fortunately they were underwritten by a National Science Foundation grant.

Everything cannot be underwritten, however, and the only long-term answer is more members. I look ahead to all the other really outstanding and important programs that we are now considering in Council and am even more firmly convinced than ever that our appeal for more money, more members, more everything is justified and right for this profession.

Election day is coming

On pages 98-99 of this issue are the selections of the Nominating Committee for A.I.Ch.E. Officers and Directors plus news about several members nominated by petition. As reported in the April News and Notes, October 3 is the last possible day for petitions to be received in this office. The ballot will have exactly the same format as last year, and so in order to get it printed and addressed on time, each mail on October 3 will be immediately scanned for any last-minute petitions, which will be checked and added to the ballot on that day.

F. J. V. A.



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